"Beautiful art on the outside and delicious physics on the inside."

28

Physics Concepts Individually Packed

PhyS NEWtONS

Phys-Newton

In this project an Art teacher (Jeff Robin) and a Physics teacher (Andrew Gloag) had students design posters to teach the California State Physics standards. We concentrated on the first two realms of the standards which cover mechanics and Newtonian physics. The physics concepts were presented as explanations for the images they put together and painted. The standards we chose covered Newton's laws of motion, gravity, energy, circular motion and projectiles. In order to present the information accurately the students had to research and learn the science well.

Explaining science in a way others can understand requires a far deeper understanding than one can get from listening to someone else in a lecture. In this way the students were challenged to become experts in their field. For the final examination students then had to become experts in everyone else's science too. We displayed the work prominently in the school, and set up peer to peer teaching sessions where students taught each other their science concepts.

Constant Speed and Average Speed

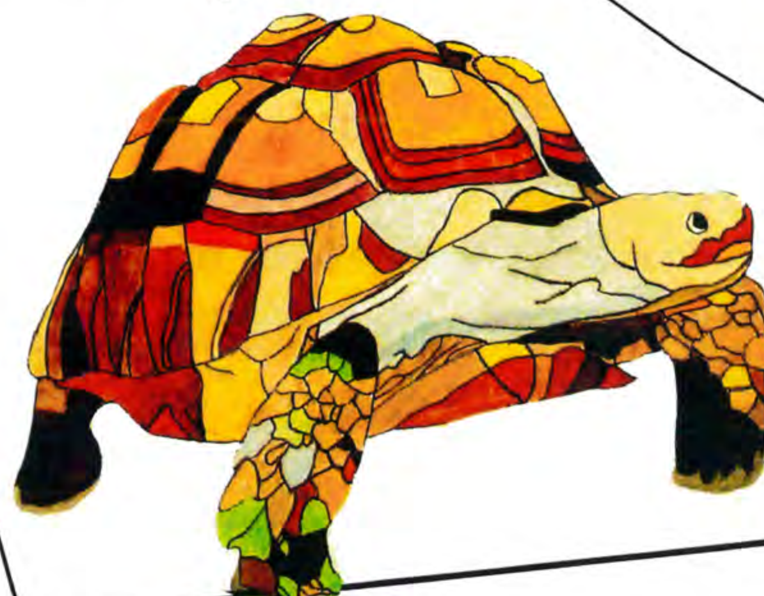
When an objects moves (such as the hare in this race) it might be constantly changing its speed. To find the average speed you would need to know the total distance the hare covers and divide it by the time it

Similarly to find an average velocity you would measure the displacement from the starting point to the ending point. After finding this you would need to divide it by the total time it took get from point A to point B. The individual speeds and the path taken would not really matter.

$$average\ speed = \frac{distance}{time}$$

$$velocity = \frac{displacement}{time}$$

$$time = \frac{distance}{speed}$$



Constant speed is when an object is always going at the same speed no matter the situation or circumstances.

$$distance = speed \cdot time$$

STANDARD 1A Students know how to solve problems that involve constant speed and average speed. *Coraima*

Newton's 1st Law:

When forces are equal, an object will remain at rest or maintain the same course and velocity. The first law states that two equal forces pushing in opposite directions will result in no change in course or direction (this includes stationary objects).

These wrestlers of equal strength exert equal forces on each other. Neither of them move, because the forces in both directions are balanced.

Two unequal forces pushing in opposite directions will result in movement against the lesser force. The wrestler is far stronger than the little girl, their forces are unequal. The little girl cannot match the wrestler's force. This imbalance causes the wrestler to move in the direction of the little girl.

Newton's ist law is the foundation of statics, a branch of physics and engineering that focuses on calculating the balanced forces

STANDARD1B Students know that when forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest (Newton's first law). *Joe*

Newton's Second Law

$F=m \cdot a$

Newton's second law states when a force is applied to an object, it will cause the object to accelerate. This is represented as force equals the product of mass and acceleration ($F=m \cdot a$).

The force is directly proportional to both mass and acceleration. If you apply more force, it will cause an increase acceleration. Likewise, if you add more mass, force will need to increase as well to keep it accelerating at the same rate.

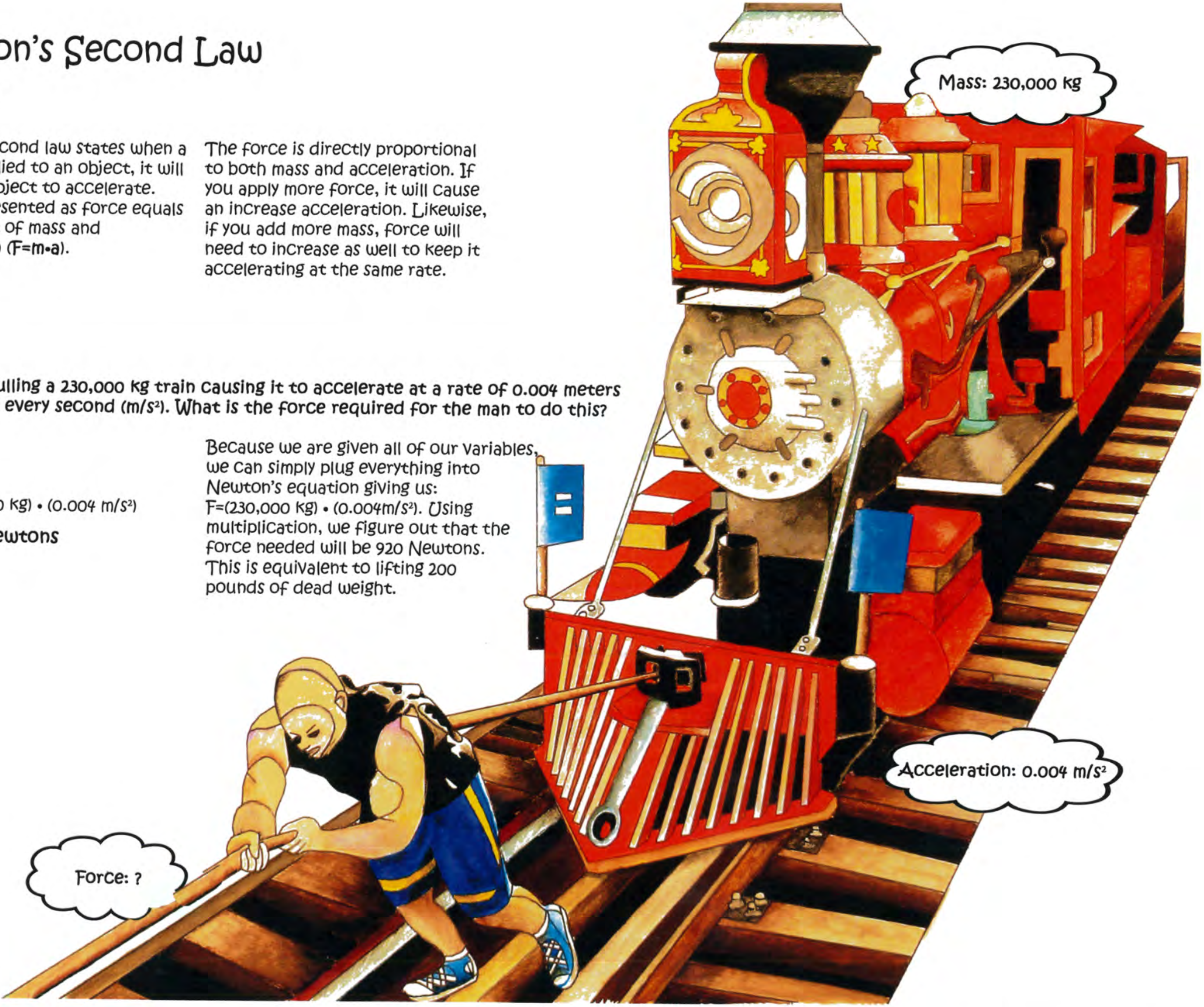
A man is pulling a 230,000 kg train causing it to accelerate at a rate of 0.004 meters per second every second (m/s^2). What is the force required for the man to do this?

$F=m \cdot a$

$F=(230{,}000\ kg) \cdot (0.004\ m/s^2)$

$F=920$ Newtons

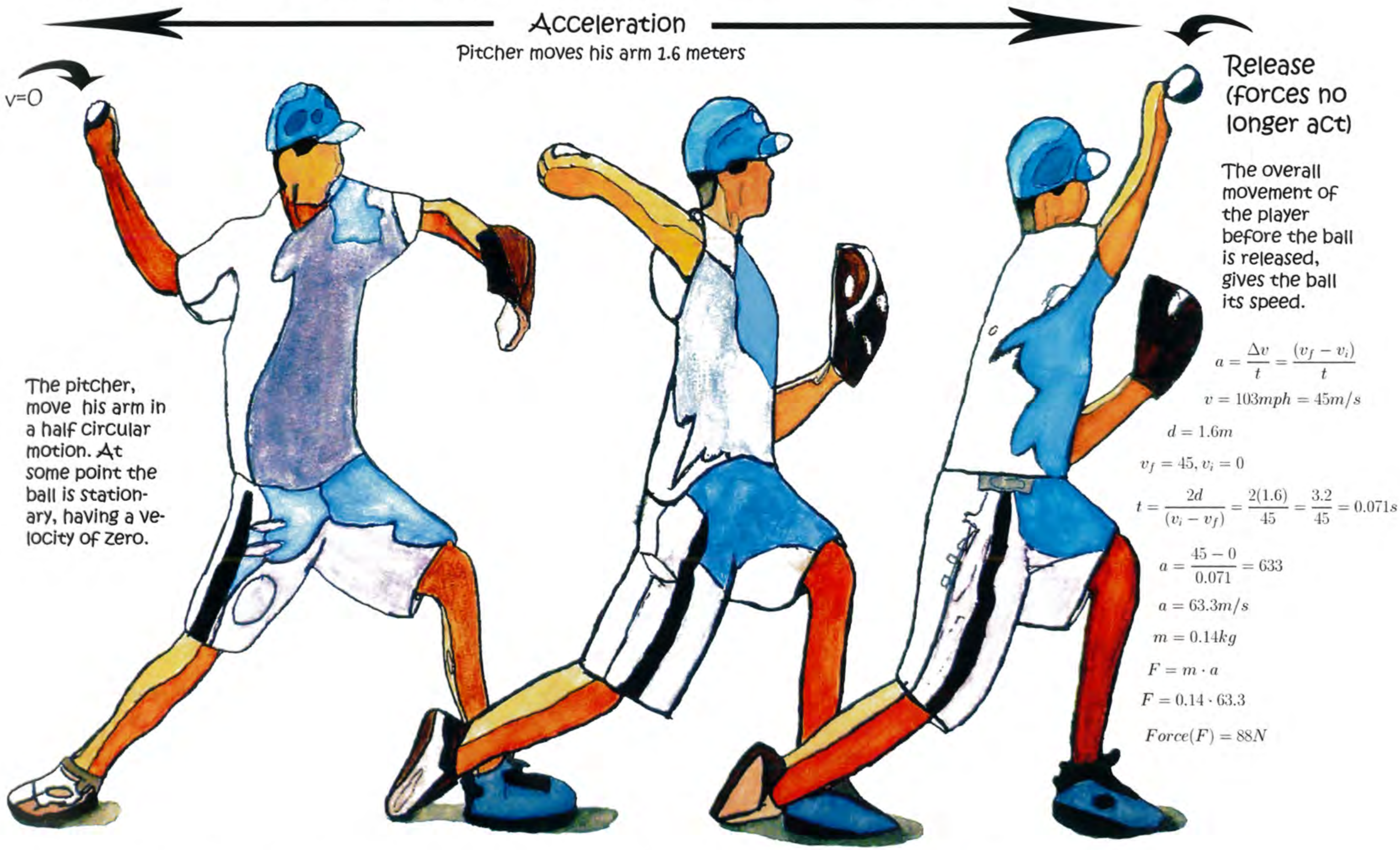
Because we are given all of our variables, we can simply plug everything into Newton's equation giving us: $F=(230{,}000\ kg) \cdot (0.004 m/s^2)$. Using multiplication, we figure out that the force needed will be 920 Newtons. This is equivalent to lifting 200 pounds of dead weight.



STANDARD1C Students know how to apply the law F=ma to solve one-dimensional motion problems that involve constant forces (Newton's second law). *Alex*

Newton's Second Law

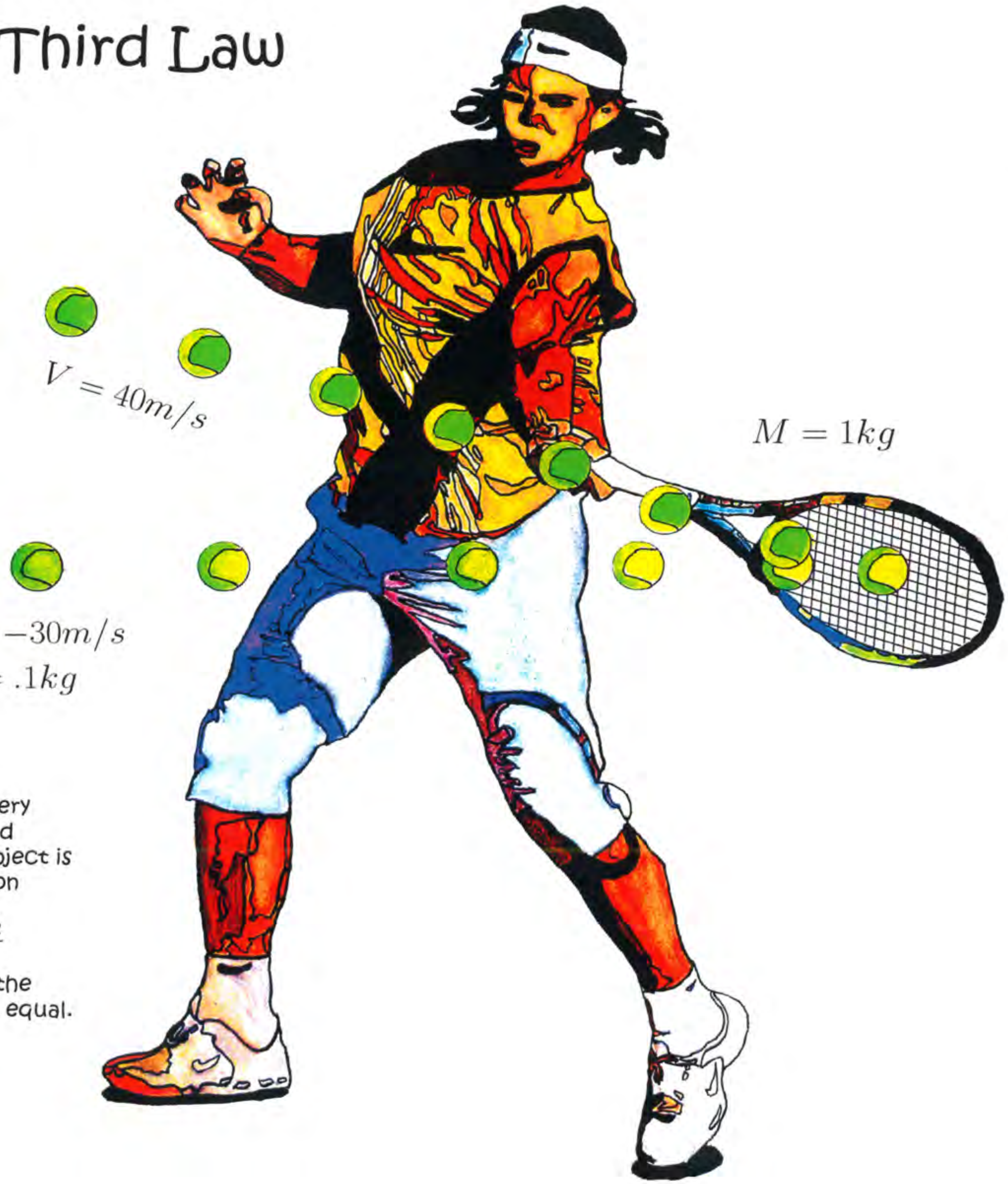
Applying a force to an object will cause that object to accelerate in a direction, which is determined by whether or not the force is a push or a pull. In the mathematical equations this is denoted by a positive or negative sign. Acceleration shows how quickly the velocity of an object is changing. Also it can be calculated by finding the total distance traveled by that object, in a certain amount of time. To find the force behind an object's velocity you plug the acceleration and mass of that object into



The pitcher uses all his force to move his hand forward as quickly as he can. This motion causes the ball to speed up, and it happens so quickly that it is barely seen by those watching.

STANDARD 1C Students know how to apply the law F=ma to solve one-dimensional motion problems that involve constant forces (Newton's second law). *Anna*

Newton's Third Law



When a tennis player hits a ball, the ball exerts a force on the racket and vice versa, causing a change in velocity in both objects. It is commonly thought that if Newton's third law states that with every action there is an equal and opposite reaction, the racket and the ball should cancel each other out. But the objects' masses are inversely proportional so the ball has a larger change in velocity than the racket. Therefore, we only see the effect on the ball.

Forces act in pairs so in every action there is an equal and opposite reaction. Each object is represented by the equation

$$\frac{M_1 \Delta V_1}{t} = \frac{M_2 \Delta V_2}{t}$$

This equation states that the forces of both objects are equal.

A tennis ball weighing .1 kg is coming at a tennis player at a velocity of -30 m/s. When the tennis player hits the ball and changes the velocity to 40 m/s, the ball's change in velocity is 70 m/s. The mass multiplied by the change in the velocity of the ball is equal to 7 N. If the tennis racket weighs 1 kg and if

$$\frac{M_1 \Delta V_1}{t} = \frac{M_2 \Delta V_2}{t}$$

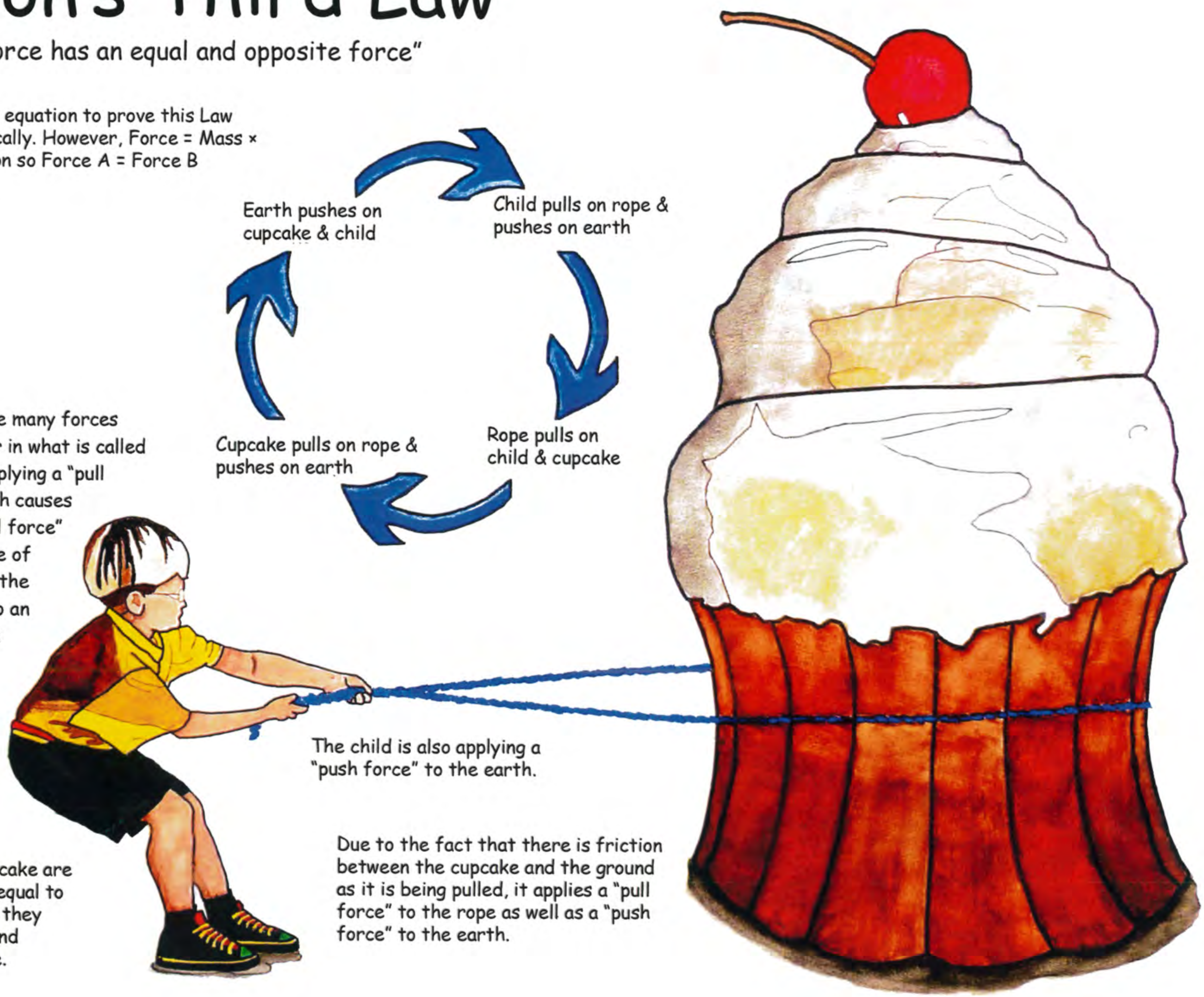
then what is the change in velocity of the ball?

STANDARD 1D Students know that when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction (Newton's third law). *James*

Newton's Third Law

"every force has an equal and opposite force"

There is no equation to prove this Law mathematically. However, Force = Mass × Acceleration so Force A = Force B



In some cases there are many forces acting upon one another in what is called a system. The boy is applying a "pull force" to the rope which causes the rope to apply a "pull force" back to the boy because of the tension created by the rope being connected to an object (Cupcake) with a larger mass.

The boy and his big cupcake are "push forces" that are equal to each other. Therefore they cancel each other out and nobody moves anywhere.

STANDARD 1D Students know that when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction (Newton's third law). *Allie*

Universal Gravitation

Every object in the universe attracts every other object with a gravitational force. Gravitational Force is directly dependent upon the mass of both objects. The bigger the objects, the stronger the force.

Gravitational Force also obeys the inverse square law. This means that if two objects (center of mass) are further away from each other they attract each other less. In fact, doubling the distance reduces the force by 4.

These examples relate to this law because the fat couple below with a higher mass and less distance between them is more attracted to each other than the skinny couple with

Using the equation below, we can find the force of attraction between both couples.

The fat couple is:

$$F_{grav} = G\frac{115 \cdot 110}{1^2}$$

$$= 11,500G$$

And the skinny couple is:

$$F_{grav} = G\frac{60 \cdot 50}{5^2}$$

$$= 120G$$

This law can be explained by the equation: $$F_{grav} = G\frac{m_1 \cdot m_2}{r^2}$$

G represents the universal gravitation constant which is 6.673×10^{-11} $m^3 kg^{-1} s^{-2}$

M1 represents the mass of object 1 in kg, m2 represents the mass of object 2 in kg, d represents the difference separating the objects center in meters.

STANDARD 1E Students know the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth. *Cherish*

Gravitation and Gravity

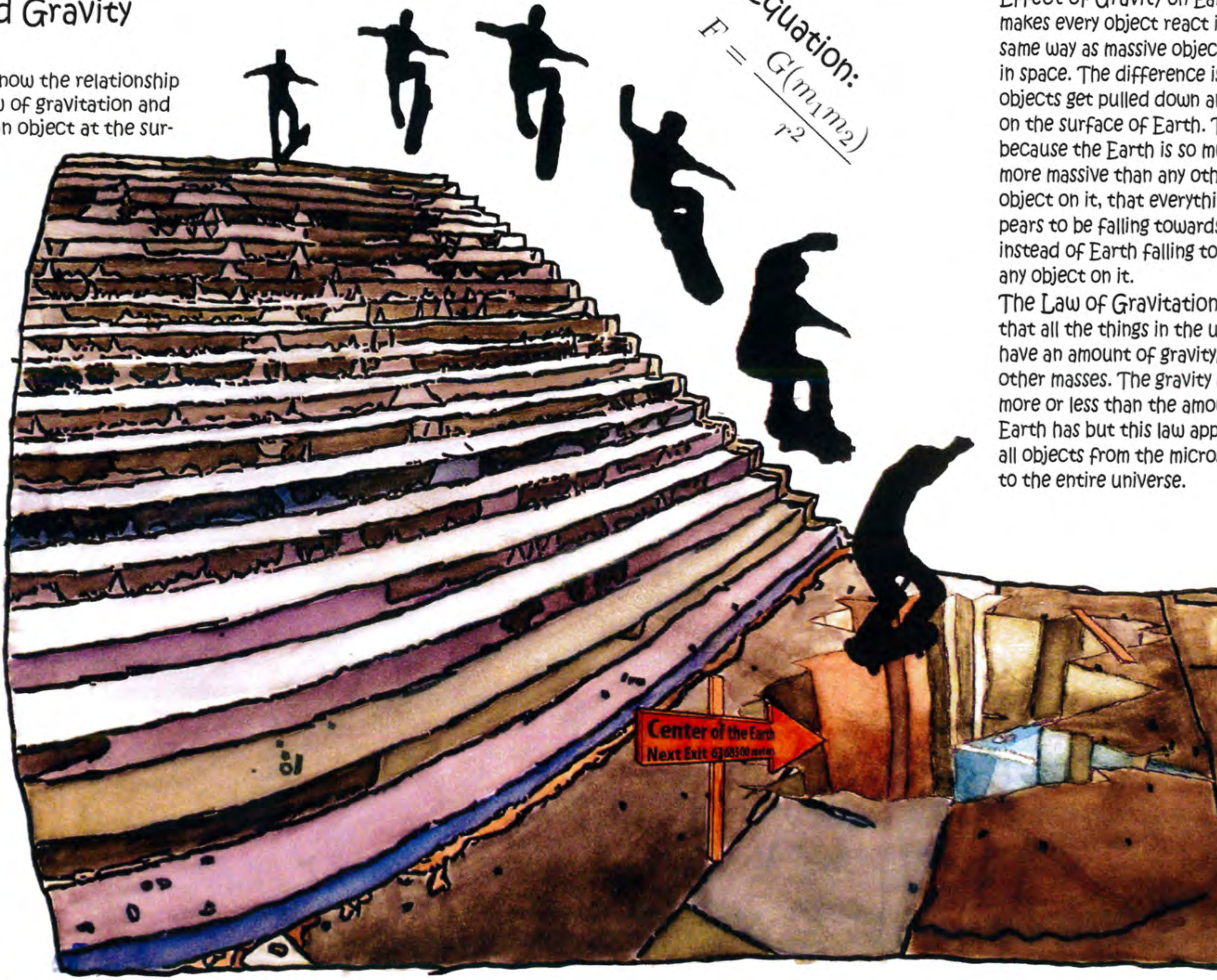
Standard: Students know the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of the Earth.

Equation: $F = \frac{G(m_1 m_2)}{r^2}$

Effect of Gravity on Earth makes every object react in the same way as massive objects react in space. The difference is that all objects get pulled down and stay on the surface of Earth. That is because the Earth is so much more massive than any other object on it, that everything appears to be falling towards Earth instead of Earth falling towards any object on it.

The Law of Gravitation means that all the things in the universe have an amount of gravity/ pull to other masses. The gravity maybe more or less than the amount the Earth has but this law applies to all objects from the microscopic to the entire universe.

In the equation the first mass is the skateboarder and the second mass is the Earth. To solve for the amount of gravity acting on the skater you would have to multiply both of the masses, then multiply by Newtons gravitational constant.
Dividing everything by the square of the Earth's radius will get you the amount of force is pulling the skater back down to Earth.



Skater : 58kg

Earth : $5.96 \times 10^{24}\ kg$

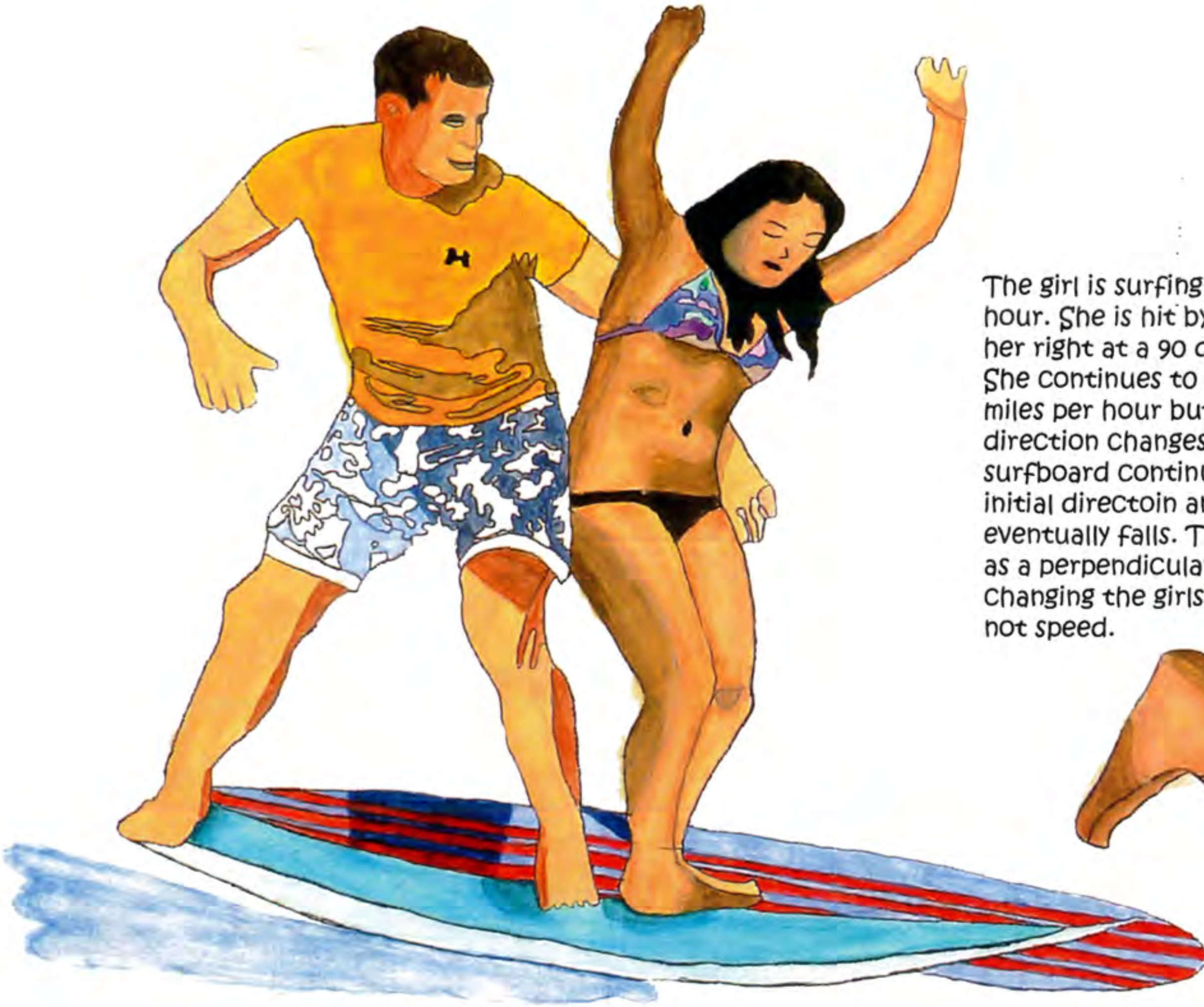
Earth's Radius : 6368500m

Newtons gravitaional constant : $6.67428 \times 10^{-11}\ N\,(m/kg)^2$

STANDARD 1E Students know the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth. *Dakota*

Perpendicular Forces

Applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed.

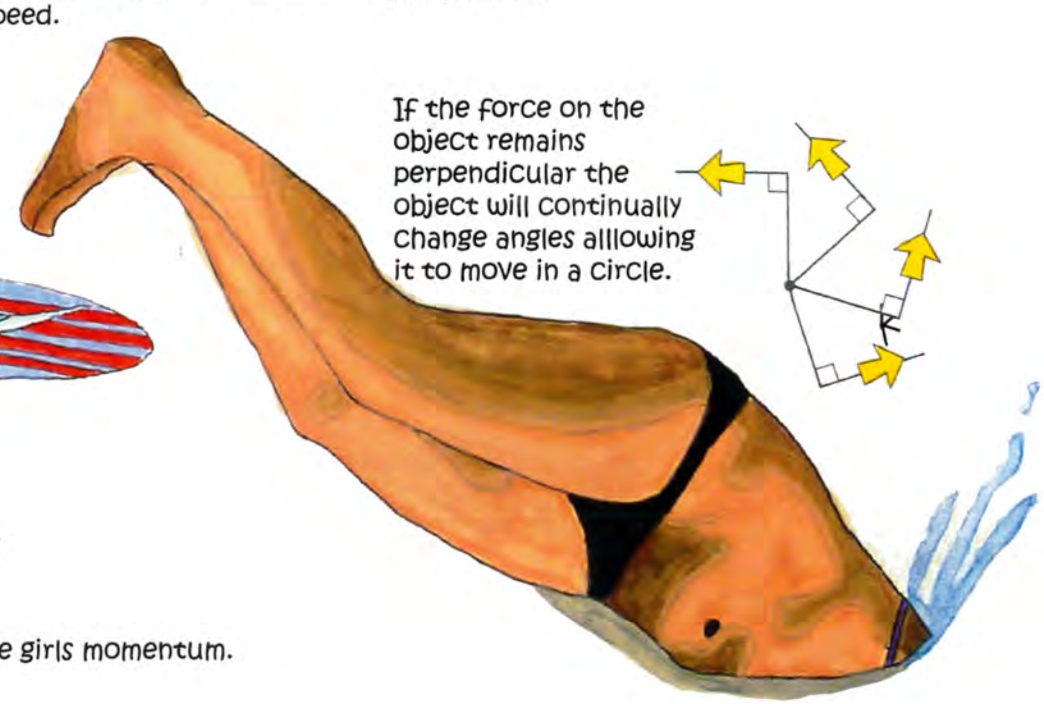


The girl is surfing at 3 miles per hour. She is hit by the man on her right at a 90 degree angle. She continues to move at 3 miles per hour but her direction changes. Her surfboard continues in her initial directoin and she eventually falls. The man acts as a perpendicular force, changing the girls direction but not speed.

Opposing forces slow objects down.

In-between is the perpendicular force. It comes at a 90 degree angle and changes the objects direction, but not speed.

Accelerating forces push objects increasing the objects current acceleration.



If the force on the object remains perpendicular the object will continually change angles alllowing it to move in a circle.

The equation used to find the acceleration of the object is

$$F = \frac{m}{a}$$

from this we find the change in the angle by using

$$\frac{d\theta}{dt} = \frac{F}{mom}$$

when mom is the girls momentum.

STANDARD 1F Students know applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed. *Hannah*

CIRCULAR MOTION

Newton's first law predicts that objects will move in a straight line. In order for an object to move in a circular path, there must be a force directing it toward the center of the circle. We call this force the centripetal (or center-seeking force). This force accelerates the object, changing the direction of motion, but because the force is at right angles to the motion, the speed is unchanged.

As the cyclists go around the curved path, a centripetal force keeps them from riding off the path in a tangential line by directing them to the center of the path. Although the cyclists travel at a constant speed, their velocities are constantly changing as they ride around the circular path.

The acceleration of an object traveling in circular motion is calculated using the following formula:

$$a = V^2/r$$

$$\text{acceleration} = \frac{\text{velocity of object}^2}{\text{radius of circle}}$$

Riding at 3 meters per second, the cyclist's hat will not fall off as long as his acceleration is less than or equal to 2 meters per second squared (m/s^2) How tight of a circle can he turn without losing his hat? Solve for r:

$2m/s^2 \le 3m/s\ /\ r$ >>> $3m/s * 2m/s^2 = r$ >>> $6m = r$ >>> radius $\le 6m$

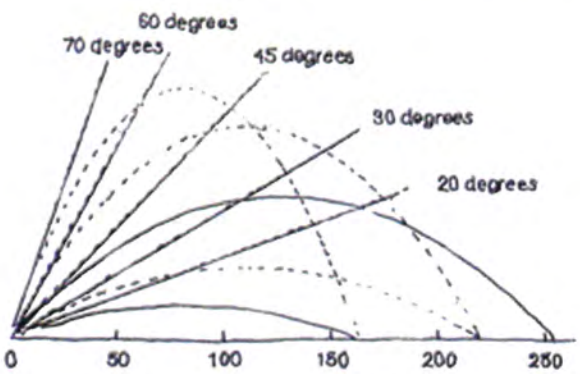
Standard 1g Students know circular motion requires the application of a constant force directed toward the center of the circle.

Marlena

Two Dimensional Trajectory

Trajectory is the path followed by an object moving through space. Generally flying objects movie in a parabola. This means that when something is thrown, shot or hit in the air the projectile will follow a parabolic path following a downward curve into the ground. The clown is followed by a parabolic path that shows two dimensional trajectory.

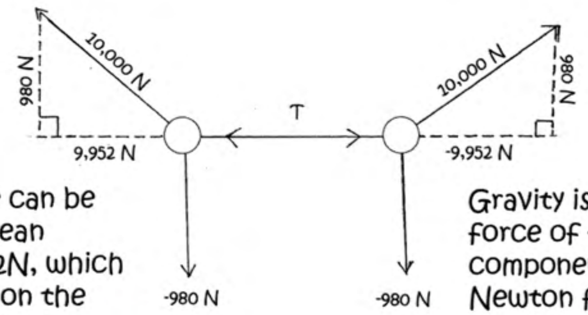
This image shows what paths projectiles may take when shot at different angles. As you can see, the 45 degree launch has the furthest distance traveled because it is optimal combination of forward velocity and height.



STANDARD 1I Students know how to solve two-dimensional trajectory problems. *Michael*

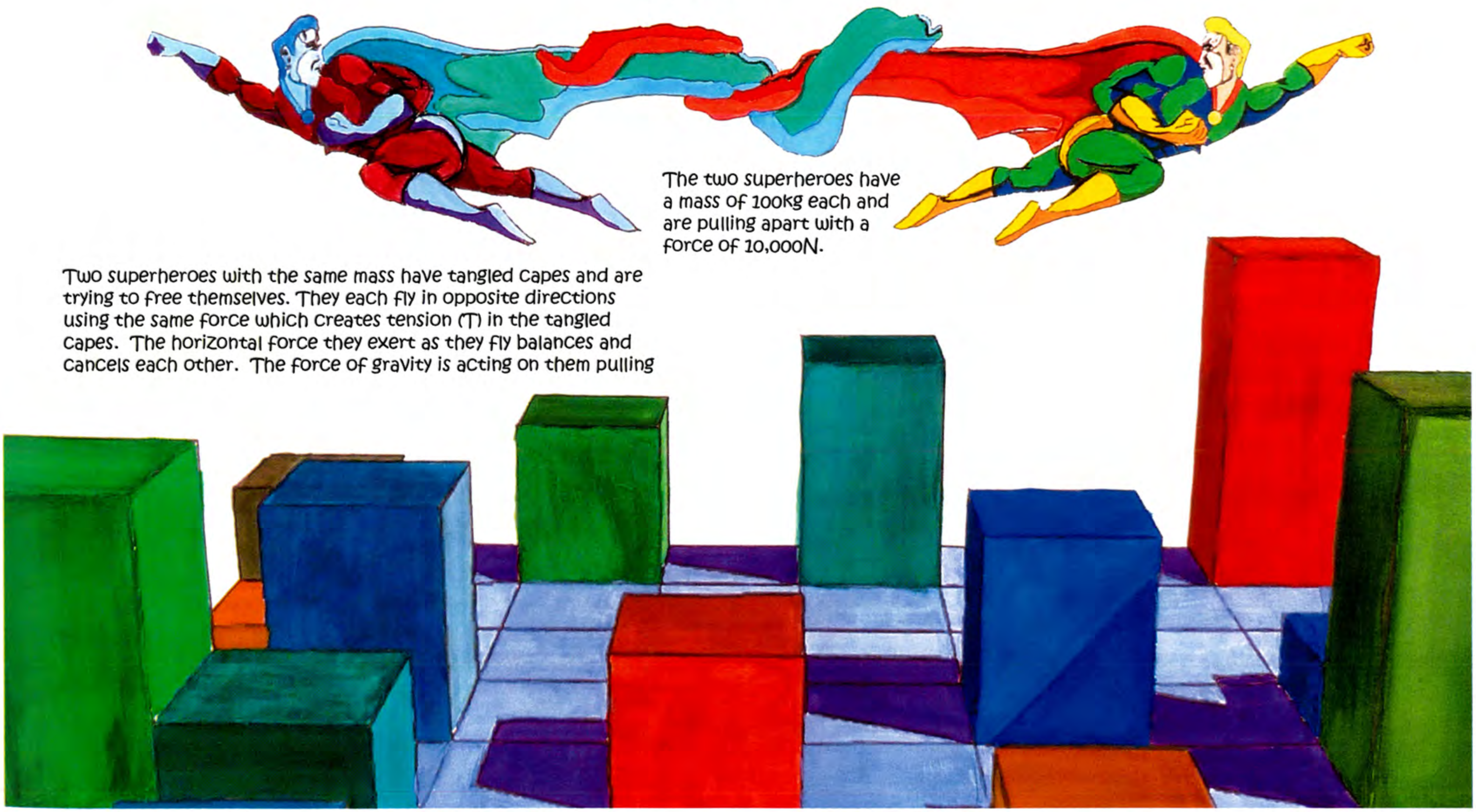
Vector Components

describes the tendency for an object to stay either at rest or at its current speed in the same direction until acted on by an outside, unbalanced force. If the sum of all the forces acting upon the object equals zero, there is no acceleration.



The horizontal force can be found with Pythagorean Theorem and is -9,952N, which means that the hero on the right is exerting 9,952N to balance it.

Gravity is pulling on them with a force of -980N. The vertical component of the 10,000 Newton force must be +980N.



The two superheroes have a mass of 100kg each and are pulling apart with a force of 10,000N.

Two superheroes with the same mass have tangled capes and are trying to free themselves. They each fly in opposite directions using the same force which creates tension (T) in the tangled capes. The horizontal force they exert as they fly balances and cancels each other. The force of gravity is acting on them pulling

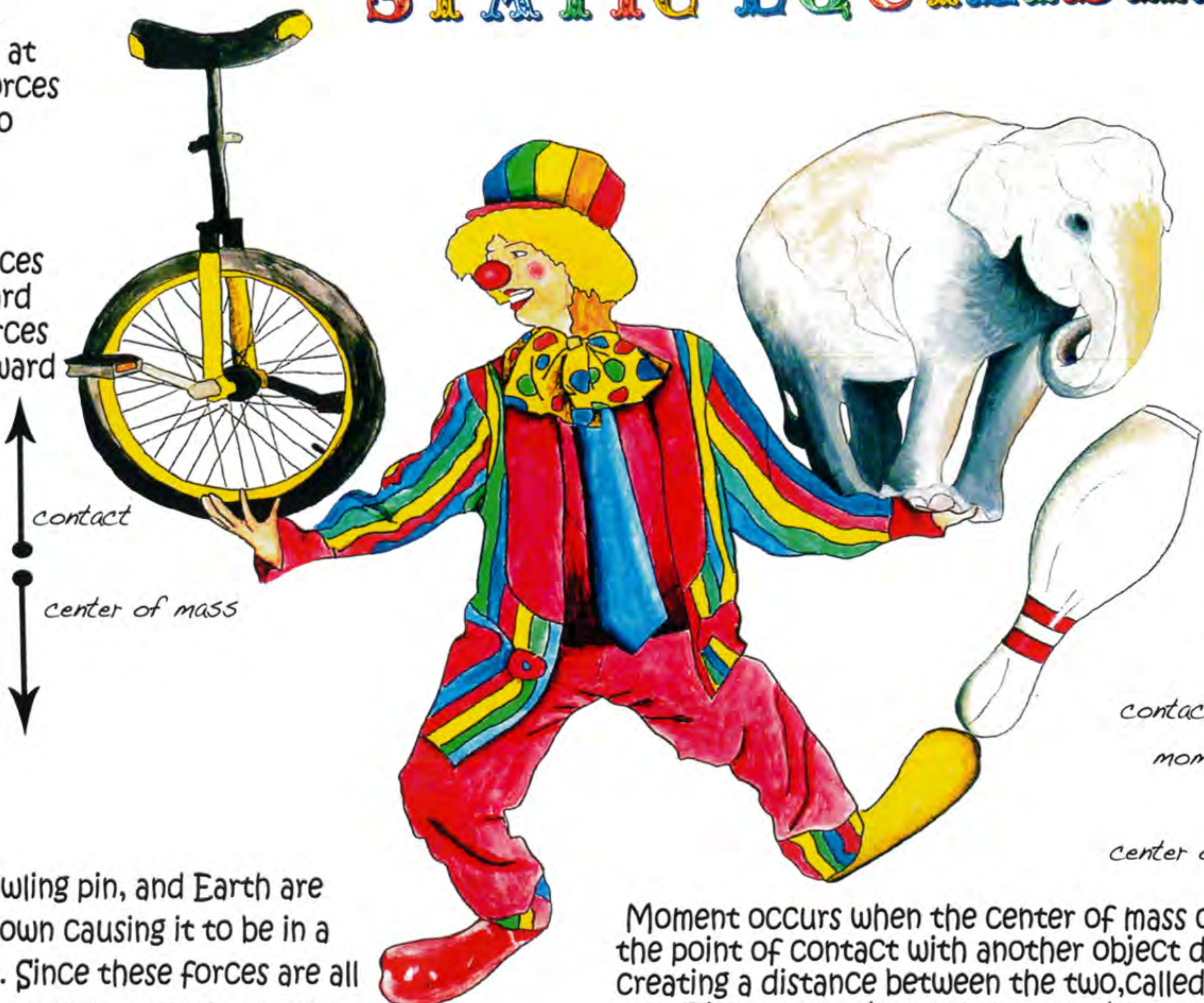
STANDARD 1J Students know how to resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components. *Danika*

STATIC EQUILIBRIUM

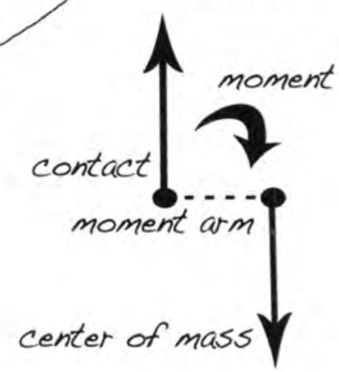
An object is in a state of "Static Equilibrium" when all the forces acting on it are balanced and the object is at rest, although all of the forces are not necessarily equal to each other.

The forces are balanced because the rightward forces are balanced by the leftward forces and the upward forces are balanced by the downward forces. This results in the forces adding up to 0.

The forces acting on the clown are all balanced because their centers of mass and points of contact align. This means there is no moment which causes an object to be unbalanced.



If there was a distance between the forces then they would not be balanced.



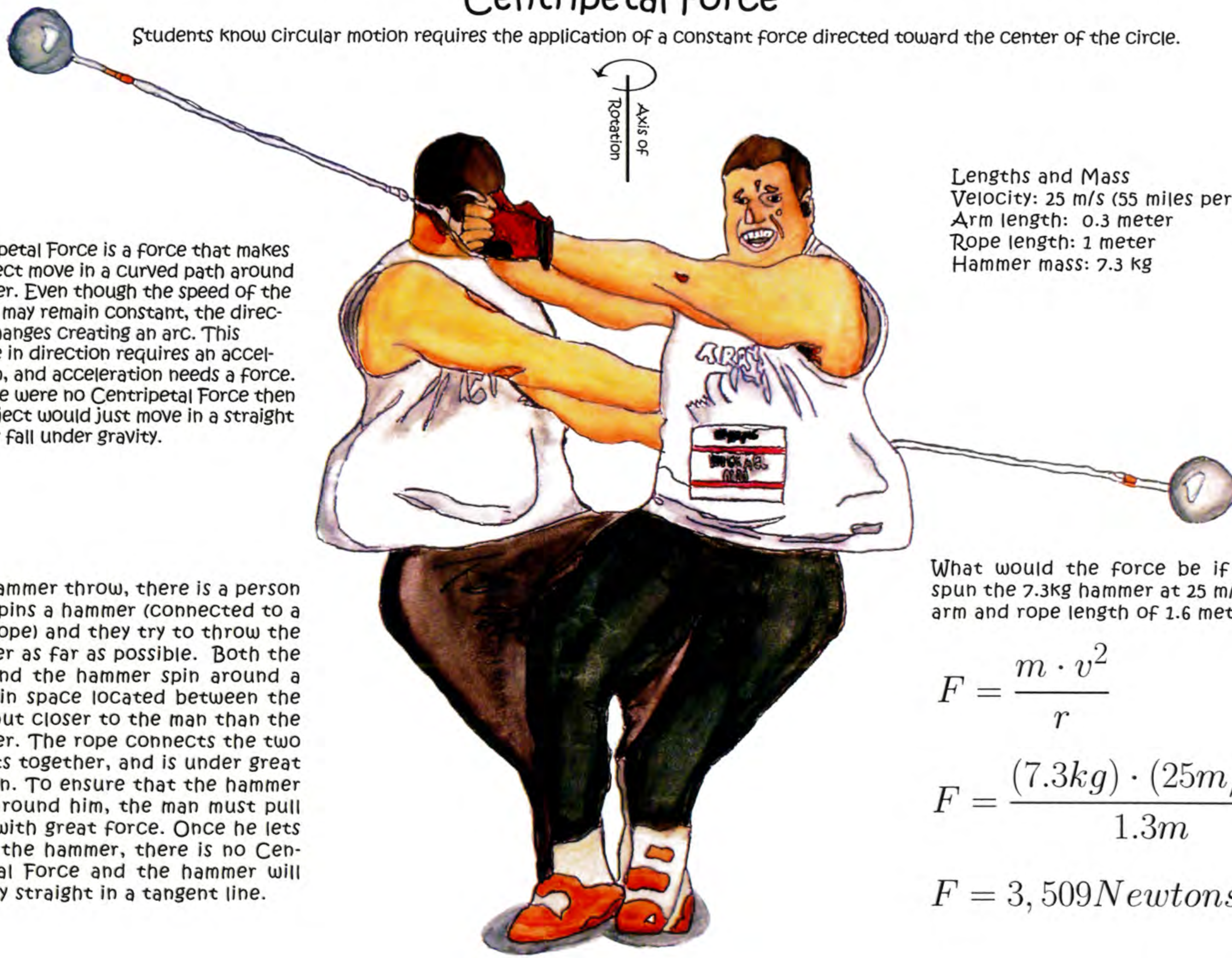
The unicycle, elephant, bowling pin, and Earth are all forces acting on the clown causing it to be in a state of static equilibrium. Since these forces are all balanced, the cancel out to create a net force of 0.

Moment occurs when the center of mass of an object and the point of contact with another object do not align, creating a distance between the two,called the moment arm. The greater the moment arm, the greater the moment.

STANDARD 1K Students know how to solve two-dimensional problems involving balanced forces (statics). *Lola*

Centripetal Force

Students know circular motion requires the application of a constant force directed toward the center of the circle.



Centripetal Force is a force that makes an object move in a curved path around a center. Even though the speed of the object may remain constant, the direction changes creating an arc. This change in direction requires an acceleration, and acceleration needs a force. If there were no Centripetal Force then the object would just move in a straight line, or fall under gravity.

In a hammer throw, there is a person that spins a hammer (connected to a wire rope) and they try to throw the hammer as far as possible. Both the man and the hammer spin around a point in space located between the two, but closer to the man than the hammer. The rope connects the two objects together, and is under great tension. To ensure that the hammer goes around him, the man must pull on it with great force. Once he lets go of the hammer, there is no Centripetal Force and the hammer will just fly straight in a tangent line.

Lengths and Mass
Velocity: 25 m/s (55 miles per hour)
Arm length: 0.3 meter
Rope length: 1 meter
Hammer mass: 7.3 kg

What would the force be if the man spun the 7.3kg hammer at 25 m/s with an arm and rope length of 1.6 meters?

$$F = \frac{m \cdot v^2}{r}$$

$$F = \frac{(7.3kg) \cdot (25m/s)^2}{1.3m}$$

$$F = 3,509 Newtons$$

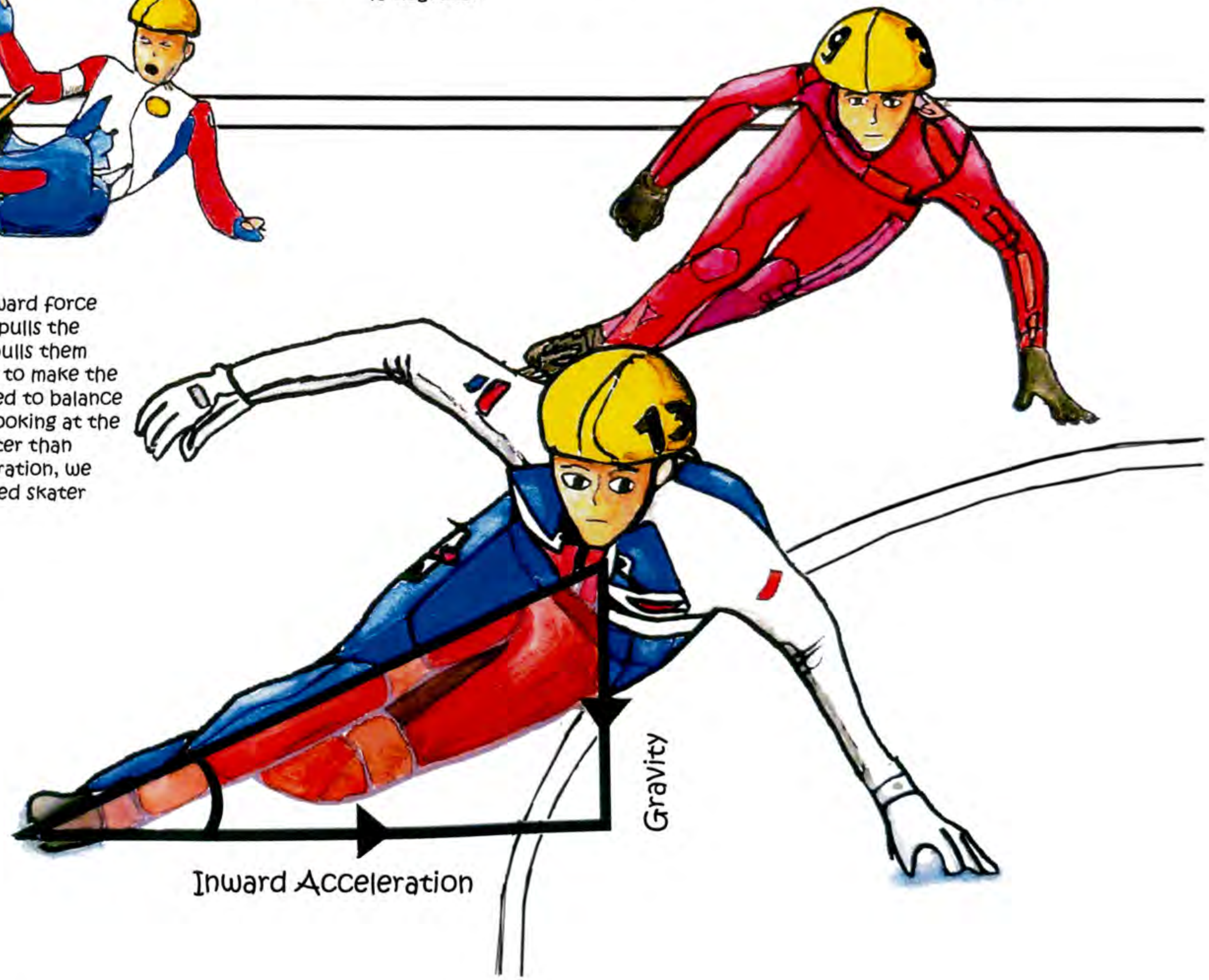
STANDARD 1L Students know how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: a=v2/r. *Jessica*

Centripetal Acceleration

is the acceleration of an object going around a curve. The acceleration is determined by the velocity of the object and the radius of the curve the object is traveling. If an object of mass (m) is traveling with constant speed (v) about a circle of radius (r), then the centripetal acceleration on the object has the magnitude:

$$a = \frac{v^2}{r}$$

When the ball is being pushed by a light wind, it hangs at a slight angle because gravity is stronger than the sideways force caused by the wind. When the speed of the wind increases, the sideways force becomes stronger and the ball rises against gravity. The angle that the ball hangs at will always be determined by the strength of the horizontal and vertical forces – when they are equal in magnitude then the ball will hang at 45 degrees.



When the speed skaters turn, both the inward force and gravity are acting upon them. Gravity pulls the speed skater down and the inward force pulls them towards the center of the circle. In order to make the turn without falling, the speed skaters need to balance the two forces by leaning. We can tell by looking at the angle that the inward acceleration is greater than gravity. Because we know gravity's acceleration, we can measure the inward pull when the speed skater turns.

Radius = 25 meters

Velocity = $\frac{6}{2}$ (ratio of trianlge)

Gravity = 9.8 m/s^2

$$a = \frac{6}{2} \times 9.8\ m/s^2$$

$$\sqrt{v^2} = \sqrt{\frac{6}{2} \times 9.8\ m/s^2 \times 25}$$

$$\sqrt{v^2} = \sqrt{735}$$

$$v = 27\ m/s^2$$

STANDARD 1L Students know how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: a=v2/r. *Kristina*

Kinetic Energy

When the bmx rider begins to fall he is going to gain kinetic energy because he will accelerate due to gravity.

$$g = 9.8\ m/s^2$$

The bmx rider and his bike weigh 85kg after one second his enegy is :

$$Ke = \tfrac{1}{2} \times 85 \times 9.8^2$$

4,080 joules

Kinetic energy is the energy that is given to an object because of its motion. Kinetic comes from the Greek word kinesis meaning motion. Kinetic energy is measured when you multiply half the mass times the velocity of an object squared, the equation is

$$Ke = \tfrac{1}{2} \times m \times v^2$$

After two seconds of falling the bmx rider and his bike will have:

$$Ke = \tfrac{1}{2} \times 85 \times (9.8 \times 2)^2$$

16,300 joules

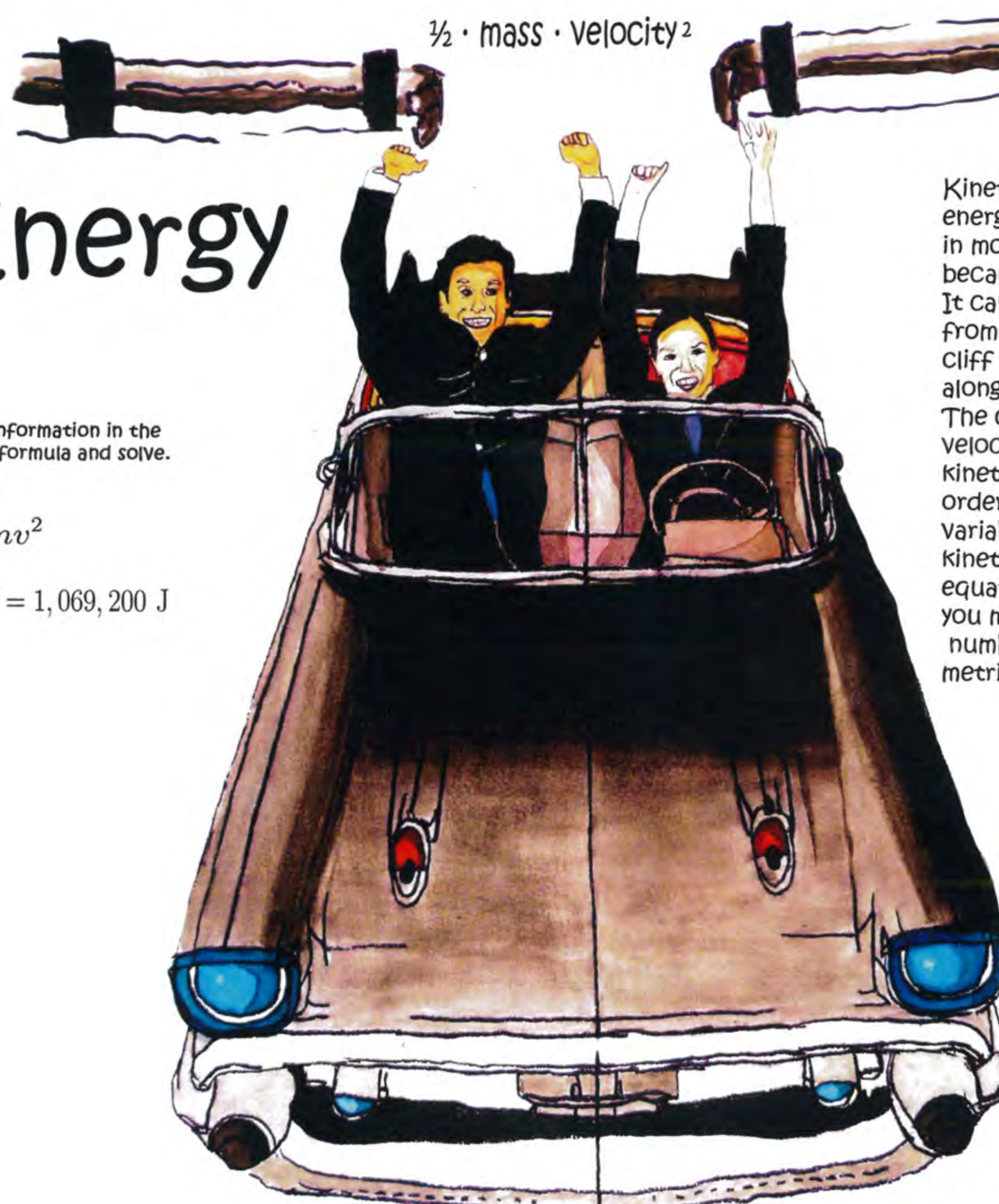
As an object falls, its kinetic energy increases as time progresses. The bmx rider's velocity is affected by gravity and is given by time multiplied by the constant of gravity:

$$v = 9.8 \times t$$

Since energy is proportional to velocity squared he will have four times the energy when he has been falling for two seconds than he would have after one second.

STANDARD 2A Students know how to calculate kinetic energy by using the formula E=(1/2)mv2 . *Manny*

Kinetic Energy



Kinetic energy is the energy that anything in motion has because of its speed. It can be anything from a car falling of a cliff to a car driving along a straight road. The cars' mass and velocity will give you kinetic energy. In order to plug in the variables into the kinetic energy equation and solve, you must have the numbers in the right metric units.

Using metric units

In 1998 NASA lost 125 million dollars because they did not catch a small mistake when it came to converting their measurments to the correct metric units. As a result the polar lander crashed on Mars.

1,609 meters = 1 mile
3,600 sec = 1 hr.
1 kg = 2.2 lbs

1. Convert pounds To kilograms.
There are 2.2 lbs in every kilogram, so to convert you would divide 3,300 lbs by 2.2:

mass = 3,300 ÷ 2.2 = 1650 kg

2. Convert miles per hour to meters per second.
There are 1609 meters in every mile and 1 hour is 3,600 seconds so we multiply 80 by 1609 (128,720 meters per hour) and then we divide by 3600.

velocity = 80 × 1609 ÷ 3600 = 36 m/s.

3. Plug in the information in the kinetic energy formula and solve.

$$\frac{1}{2}mv^2$$

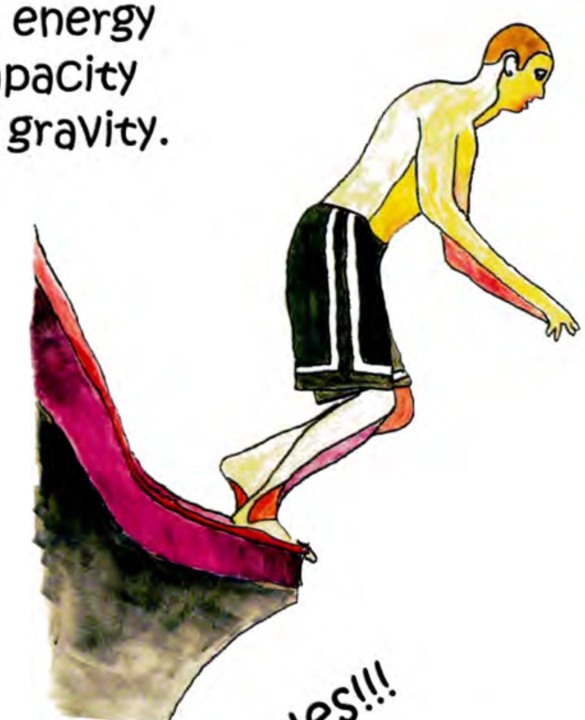
$$\frac{1}{2} \cdot 1650 \cdot 36^2 = 1,069,200 \text{ J}$$

What is the Kinetic Energy of a 3,300lbs. car falling off a cliff at 80 mph?

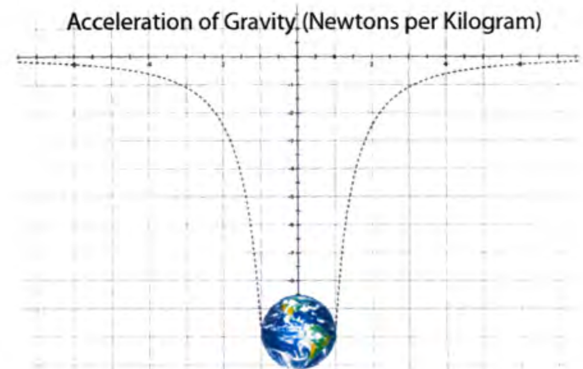
STANDARD 2A Students know how to calculate kinetic energy by using the formula E=(1/2)mv2 . *Fernanda*

Gravitational potential energy is an object's stored capacity to do work because of gravity.

A man climbs up a ladder to get on top of his roof. Constantly fighting gravity, he exerts work in each step. Finally, after the climb, the man reaches his roof and basks in gravitational potential energy.



When the man climbed up to his roof he gained potential energy at a nearly constant rate. If he got far enough away from the earth he would notice gravity getting weaker. The graph below shows how the acceleration of gravity starts to asymptote once an object gets several earth radii away.



The graph shows force of gravity over distance. An earth is shown for scale.

$$U_g = mgh$$

$$U_g = 65 \times 9.8 \times 10$$

= 6370 Joules!!!

Mass of object(kg)

Acceleration of gravity (N/kg)

Height above ground (m)

The gravitational potential energy is equal to the energy needed to raise an object and the energy it would gain when falling back down. All the energy is conserved, it just changes form.

STANDARD 2B Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) =mgh (h is the change in the elevation). *Owen*

CONSERVATION OF E N E R G Y

The word "Kinetic" is derived from the Greek word that means "to move" and thus Kinetic Energy is the energy an object has because of its motion". Potental Energy is the energy it has because of its chance of falling under the force of gravity. The Kinetic Energy of an object is dependent on the object's mass and velocity.Potential Energy is on an objects mass, its height and the acceleration due to gravity.

$$KE = \frac{1}{2}mv^2 \quad PE = mgh$$

Orangutang's mass (50 kg)
Monkey's mass (25 kg).
Acceleration due to gravity (9.81 m/s^2)
Velocity measured in: meters/second
Energy is measured in Joules (J)

As they drop they lose potential energy as their height decreases. The potential energy loss is equal to the gain in kinetic energy.

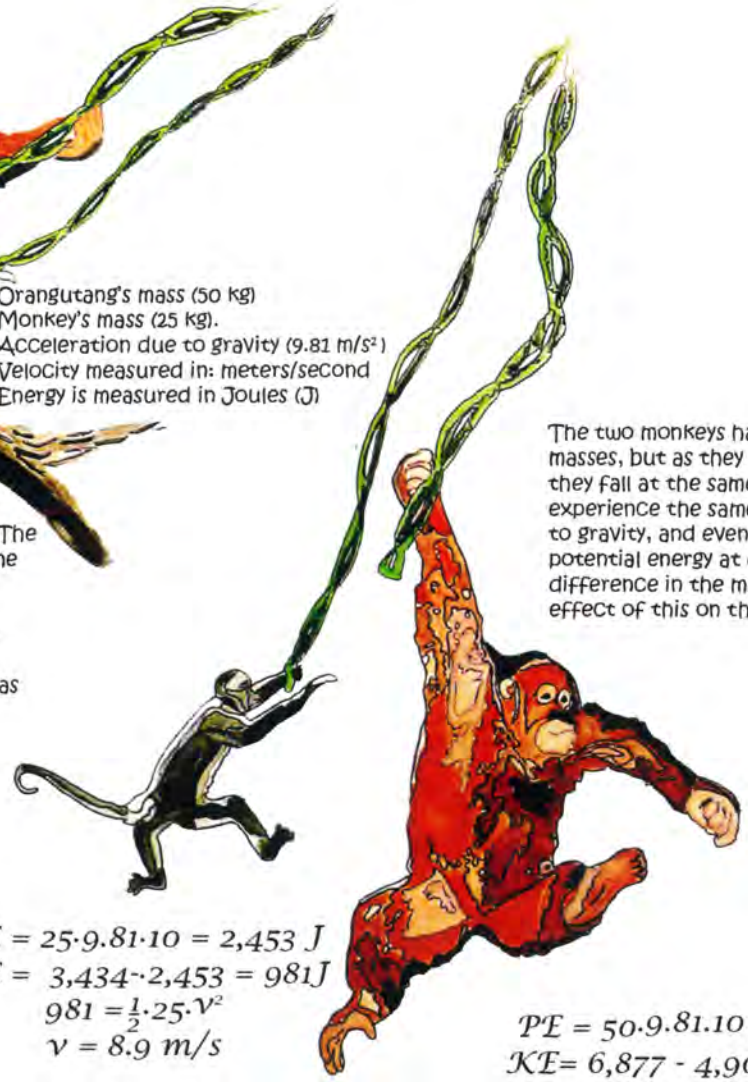
Itf the two monkeys start from a height of 14 meters then their potential energies are calculated as follows:

Orangutang:

$PE = 50 \cdot 9.81 \cdot 14$
$= 6{,}867 J$

Smaller monkey:

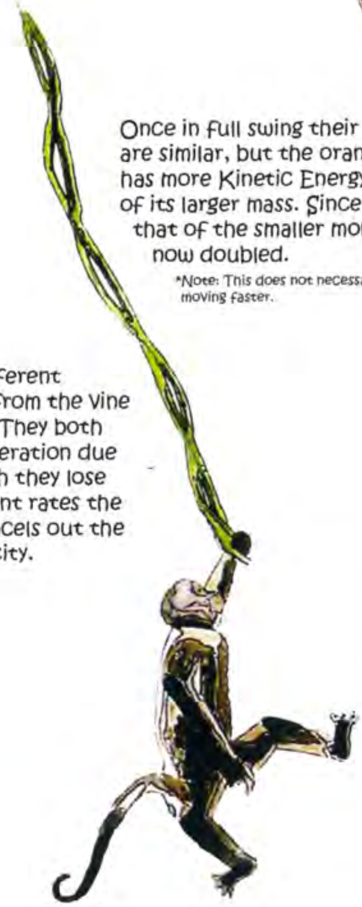
$PE = 25 \cdot 9.81 \cdot 14$
$= 3{,}434 J$



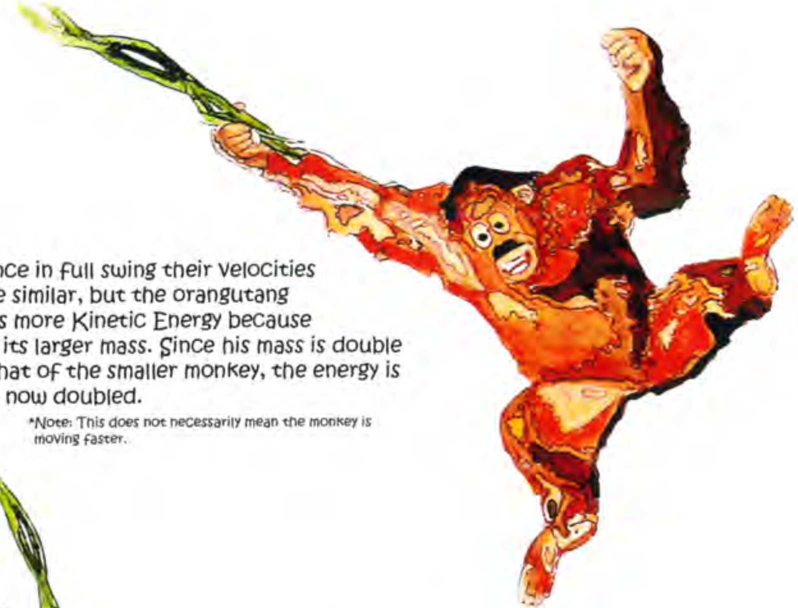
$PE = 25 \cdot 9.81 \cdot 10 = 2{,}453\ J$
$KE = 3{,}434 \text{--} 2{,}453 = 981 J$
$981 = \frac{1}{2} \cdot 25 \cdot v^2$
$v = 8.9\ m/s$

The two monkeys have different masses, but as they swing from the vine they fall at the same rate. They both experience the same acceleration due to gravity, and even though they lose potential energy at different rates the difference in the mass cancels out the effect of this on the velocity.

$PE = 50 \cdot 9.81.10 = 4{,}905\ J$
$KE = 6{,}877 - 4{,}905 = 1{,}962 J$



$1{,}962 = \frac{1}{2} \cdot 50 \cdot v^2$
$v = 8.9\ m/s$



Once in full swing their velocities are similar, but the orangutang has more Kinetic Energy because of its larger mass. Since his mass is double that of the smaller monkey, the energy is now doubled.

*Note: This does not necessarily mean the monkey is moving faster.

If the velocity is doubled, the energy is four times as much.
There is a higher increase in Kinetic Energy if you double the velocity than if you double the mass.

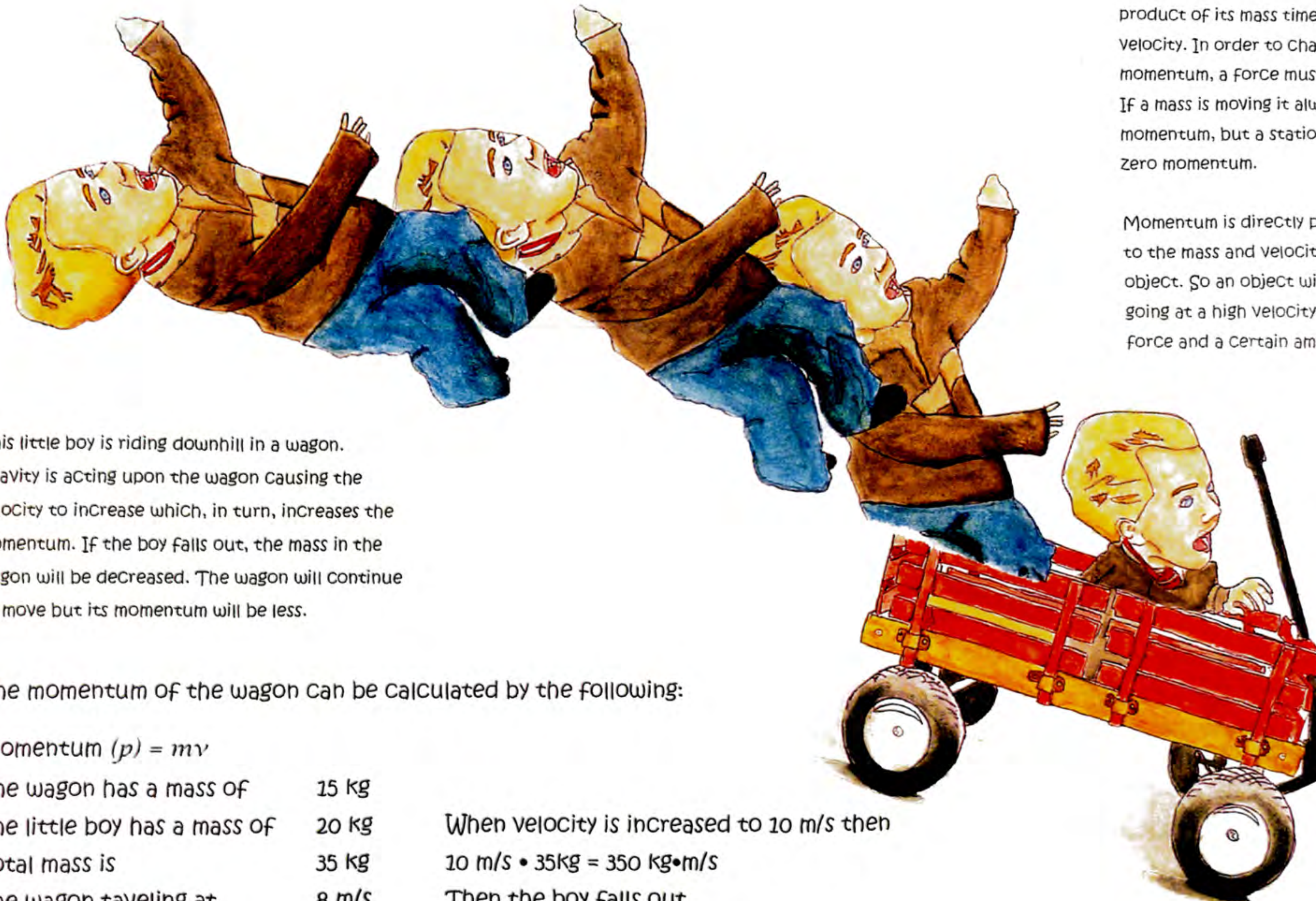
For this reason a drop of 10 meters does not result in twice the velocity increase when compared to a drop of 5 meters. To doule the speed from a 5 meter drop the monkeys would need to drop from a height of 20 meters.

STANDARD 2C Students know how to solve problems involving conservation of energy in simple systems, such as falling objects.
Kathleen

momentum = mv

The momentum of an object is the product of its mass times its velocity. In order to change the momentum, a force must be applied. If a mass is moving it always has momentum, but a stationary mass has zero momentum.

Momentum is directly proportional to the mass and velocity of a moving object. So an object with a big mass going at a high velocity will take a big force and a certain amount of time.



This little boy is riding downhill in a wagon. Gravity is acting upon the wagon causing the velocity to increase which, in turn, increases the momentum. If the boy falls out, the mass in the wagon will be decreased. The wagon will continue to move but its momentum will be less.

The momentum of the wagon can be calculated by the following:

Momentum $(p) = mv$

The wagon has a mass of	15 kg
The little boy has a mass of	20 kg
Total mass is	35 kg
The wagon taveling at	8 m/s

8 m/s • 35kg = 280 kg•m/s

When velocity is increased to 10 m/s then

10 m/s • 35kg = 350 kg•m/s

Then the boy falls out

35 kg – 20kg = 15kg

10m/s • 15kg = 150kg•m/s

STANDARD 2D Students know how to calculate momentum as the product mv. *Anna*

Momentum

Momentum is a quantity given by the product of a mass and its velocity.

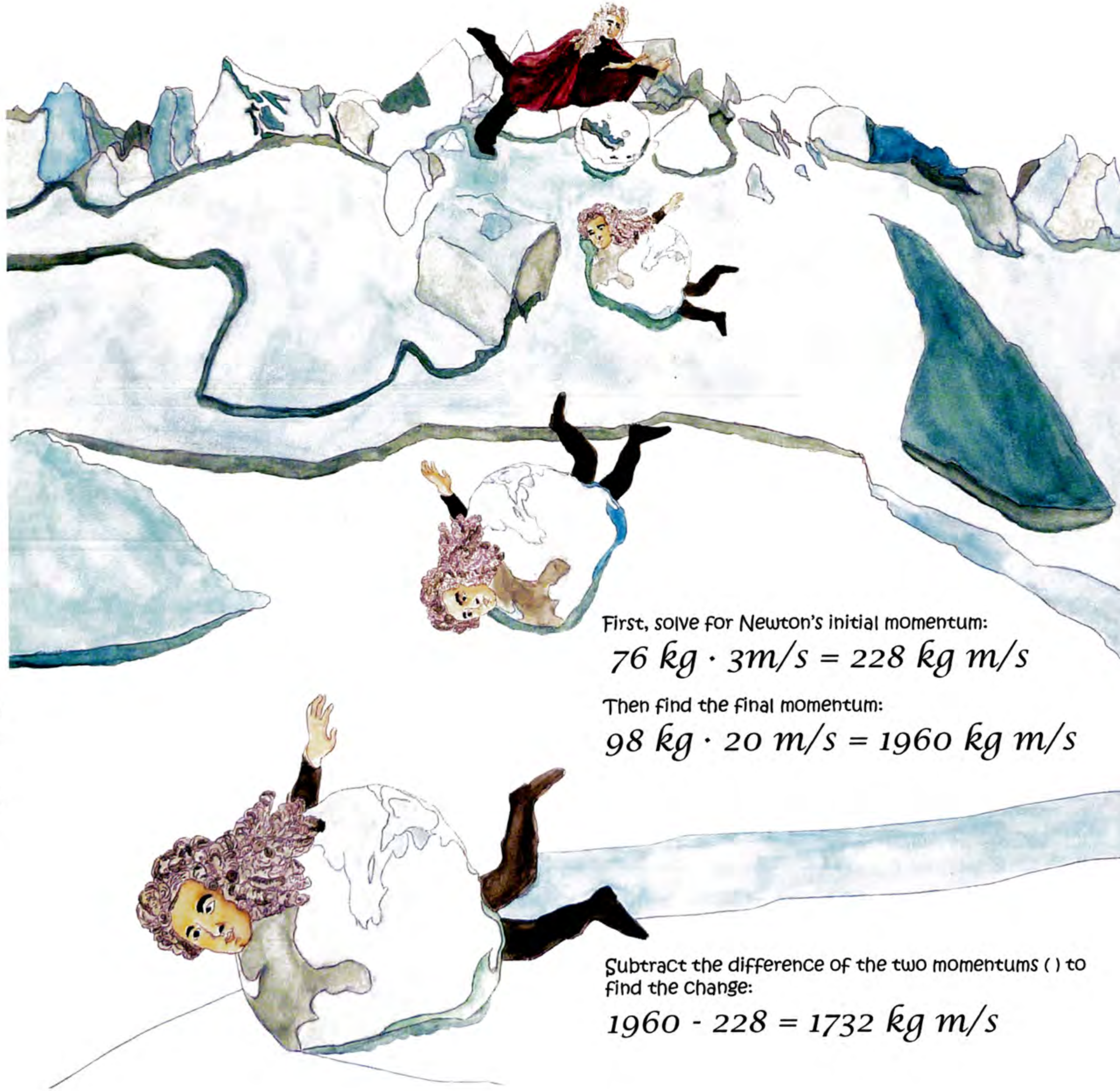
$$p = m \cdot v$$

For an object to have momentum, it must be in motion. Therefore, an object at rest has zero momentum. The higher an object's momentum, the more effort will be required to produce a significant change in velocity.

Sir Isaac Newton loses his balance and falls down a hill. As Newton rolls down the hill, he picks up snow and his mass begins to increase. The longer he goes, the more momentum he gains.

With such a high momentum, it is difficult for the snowball to come to rest until it reaches the bottom of the hill.

Sir Isaac Newton is rolling down a hill. His mass is at 76 kg and he is initially moving at a velocity of 3 m/s. When Newton reaches the bottom of the hill, he is moving at a velocity of 20 m/s, and his mass has increased to 98 kg. What is the change in momentum?



First, solve for Newton's initial momentum:

$$76\ kg \cdot 3 m/s = 228\ kg\ m/s$$

Then find the final momentum:

$$98\ kg \cdot 20\ m/s = 1960\ kg\ m/s$$

Subtract the difference of the two momentums ( ) to find the change:

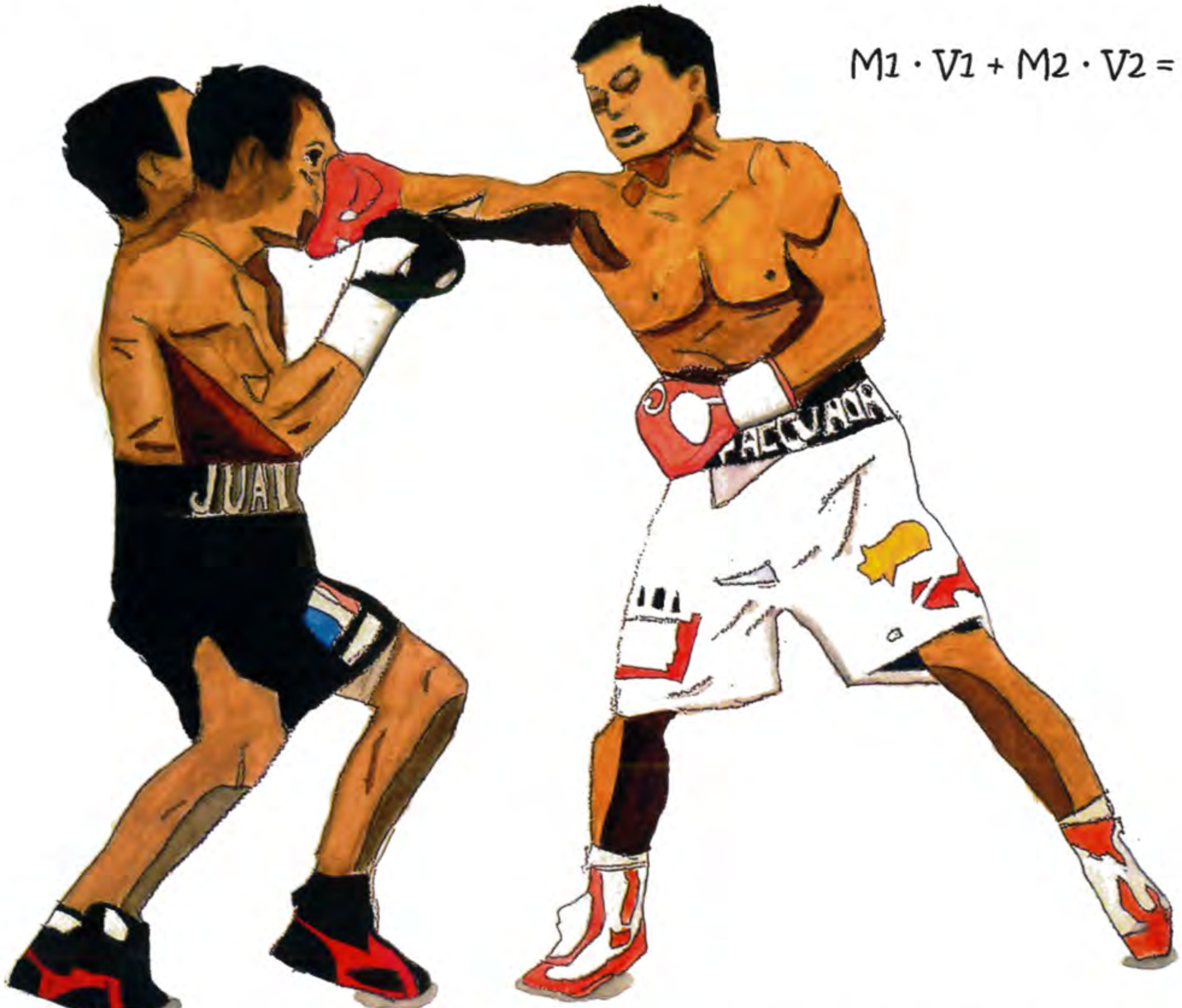
$$1960 - 228 = 1732\ kg\ m/s$$

STANDARD 2D Students know how to calculate momentum as the product mv. *Carla*

Inelastic Collisions

When an object hits another object and does not rebound or bounce off it is an inelastic collision. In a perfectly inelastic collision both objects move in a direction at the same final velocity. In this collision momentum is conserved.

$$M1 \cdot V1 + M2 \cdot V2 = (M1+M2) \cdot (Vf)$$



$(3\ Kg) \cdot (14\ m/s) + (6\ kg) \cdot (0) = (3\ kg + 6\ kg) \cdot (Vf)$

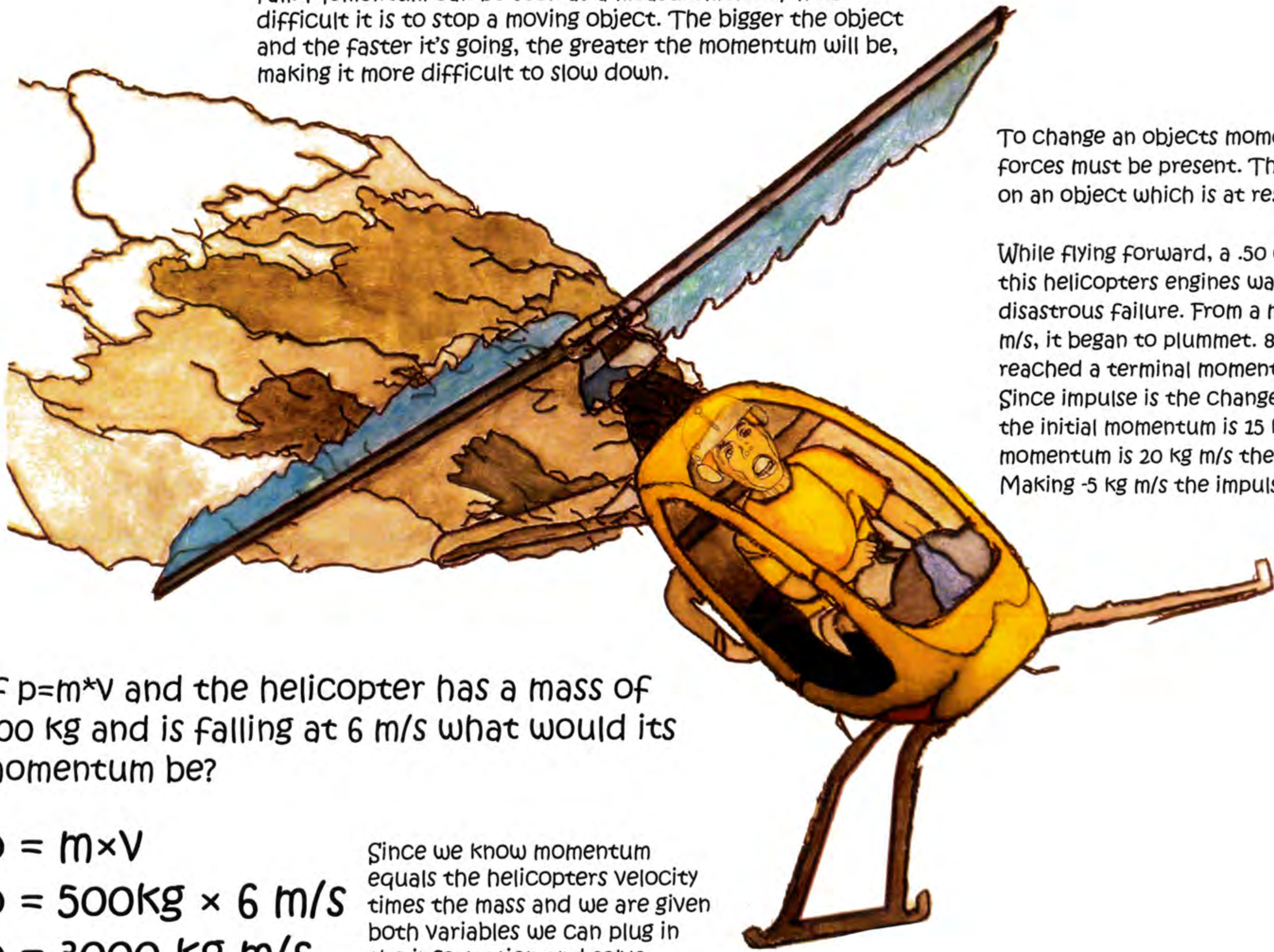
The Final Velocity = 4.7 m/s or around 10 mph

The boxer hits his opponent square in the face. At the moment of contact the mass of his hand and his opponents face move together. They both travel at the same speed at the point of contact in the same direction. Momentum is carried through both the hand and the face.

STANDARD 2E Students know momentum is a separately conserved quantity different from energy. *Isidro*

Momentum from Unbalanced Forces

If gravity is stronger than the lift of the helicopter the forces will be unbalanced, thus changing its momentum and making it fall. Momentum can be seen as a measurement of how difficult it is to stop a moving object. The bigger the object and the faster it's going, the greater the momentum will be, making it more difficult to slow down.



To change an objects momentum unbalanced forces must be present. These forces can act on an object which is at rest or moving.

While flying forward, a .50 caliber bullet pierced this helicopters engines walls and caused a disastrous failure. From a momentum of 15 kg m/s, it began to plummet. 8 seconds later it reached a terminal momentum of 20 kg m/s. Since impulse is the change of momentum and the initial momentum is 15 kg m/s and the final momentum is 20 kg m/s the change is 15 - 20. Making -5 kg m/s the impulse force.

If p=m*v and the helicopter has a mass of 500 kg and is falling at 6 m/s what would its momentum be?

$p = m \times v$

$p = 500kg \times 6\ m/s$

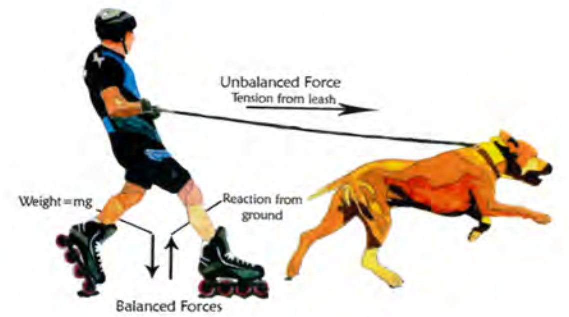
$p = 3000\ kg\ m/s$

Since we know momentum equals the helicopters velocity times the mass and we are given both variables we can plug in the information and solve.

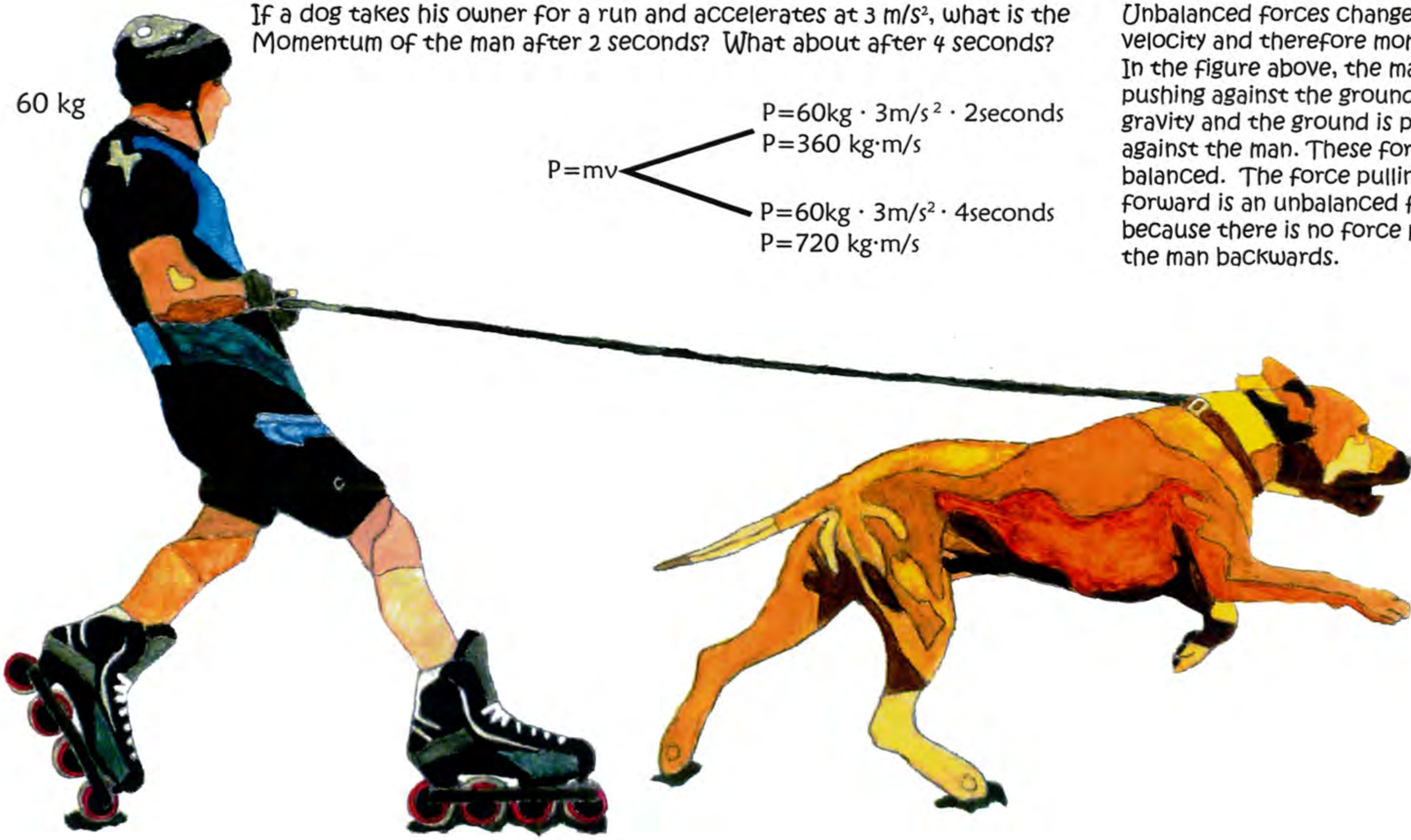
Standard 2f Students know an unbalanced force on an object produces a change in its momentum. *Edmund*

Unbalanced Forces Changing Momentum

The change in velocity caused by the acceleration of the dog changes the momentum of the man. Momentum is the strength of motion. If the mass or velocity of an object changes then the momentum also changes. Impulse is the change in momentum. If the velocity changes, the change in momentum is the impulse. Therefore impulse can be calculated as I=Ft



If a dog takes his owner for a run and accelerates at 3 m/s^2, what is the Momentum of the man after 2 seconds? What about after 4 seconds?



$P = mv$

$P = 60kg \cdot 3m/s^2 \cdot 2seconds$
$P = 360\ kg \cdot m/s$

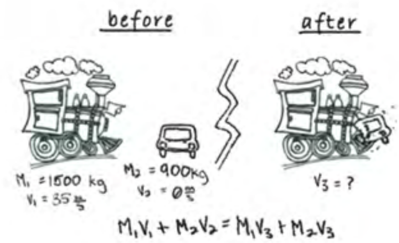
$P = 60kg \cdot 3m/s^2 \cdot 4seconds$
$P = 720\ kg \cdot m/s$

Unbalanced forces change the velocity and therefore momentum. In the figure above, the man is pushing against the ground due to gravity and the ground is pushing against the man. These forces are balanced. The force pulling the man forward is an unbalanced force because there is no force pushing the man backwards.

STANDARD 2F Students know an unbalanced force on an object produces a change in its momentum. *Zach*

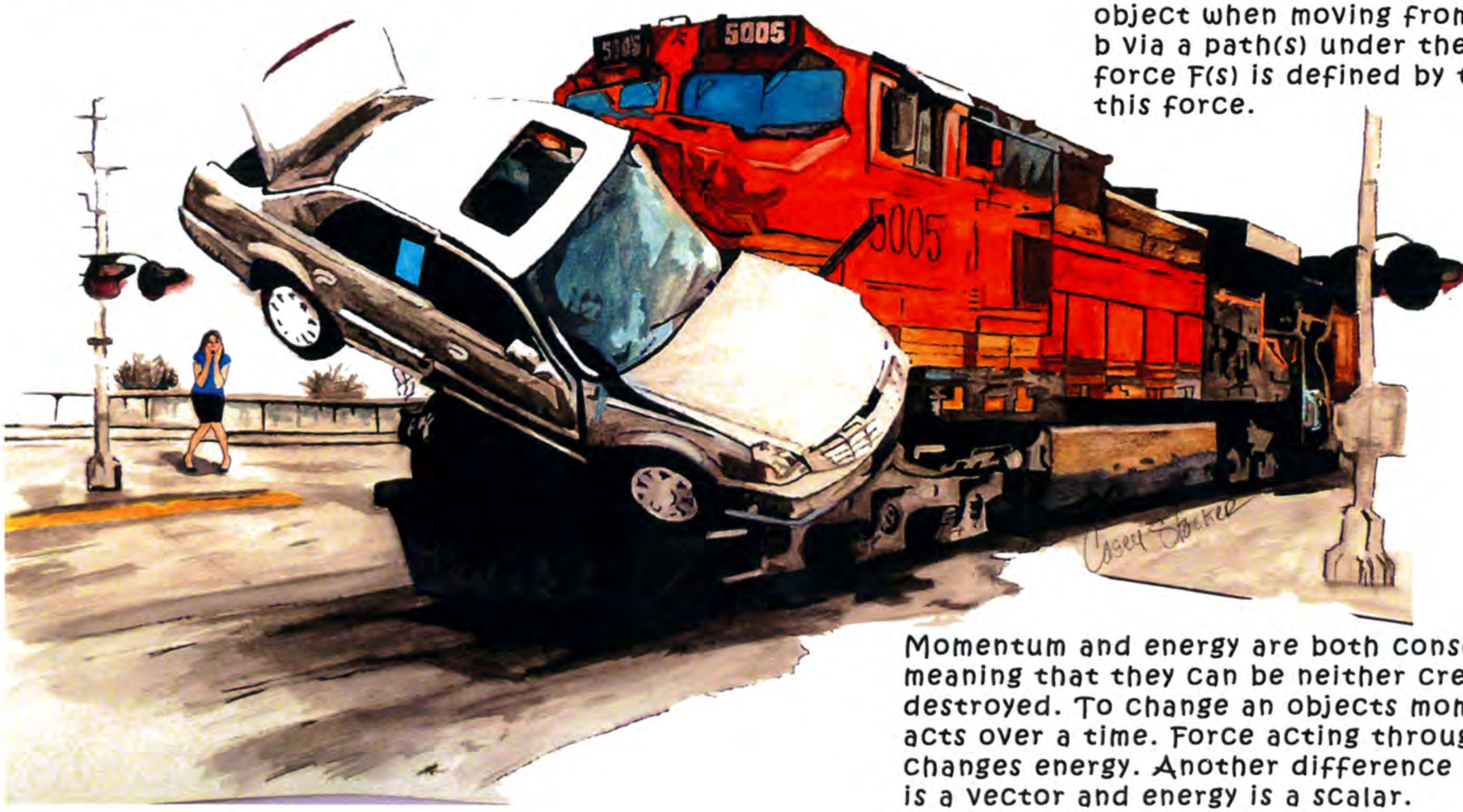
Conservation of Momentum and Energy

A train racing down the tracks hits a car. What happens to the train's kinetic energy? What happens to the train's momentum? The train's energy transforms, becoming Mechanical, Thermal and Kinetic energy, where the overall quantity of energy is conserved. The train's momentum partially transfers to the car at impact, and is conserved. See the



Momentum can be thought of as:antity of motion" that an object has: a moving car has some quantity of motion, but a parked car has none. Momentum is found by multiplying an object's mass times its speed. There is no special unit, so the units are kg × m/s. Momentum = mass (kg) × speed (m/sec).When a moving object collides with another object (moving or not) there is a transfer of momentum. The transfer is such that the total momentum before and after the collision remains equal.

The change of kinetic energy(ΔK) of an object when moving from point a to point b via a path(s) under the influence of a force F(s) is defined by the work done by this force.



Momentum and energy are both conserved quantities, meaning that they can be neither created nor destroyed. To change an objects momentum a force acts over a time. Force acting through a distance changes energy. Another difference is that momentum is a vector and energy is a scalar.

STANDARD 2G Students know how to solve problems involving elastic and inelastic collisions in one dimension by using the principles of conservation of momentum and energy. *Casey*

Impulse

We know that Newton's second law of physics is force equals mass times acceleration, and that acceleration equals the change in velocity over the change in time, then we can concur that force equals mass times the change in velocity over the change in time.

$$F = \frac{m\Delta v}{\Delta t}$$

Using algebra, we can rearrange the equation so that the change in time is on the left of the equation.

$$F\Delta t = m\Delta v$$

This equation is known as "impulse", and it mimics the equation for momentum.

$$F = mv$$

Because we have the change in velocity in the impulse equation, we can find the change in momentum.

$$m\Delta v$$

Let's examine the picture below.

The woman's hand weighs 0.25 kilograms, and is moving at a velocity of 20 meters per second.

Her hand and his cheek were in contact for 0.03 seconds. But how much force did her hand exert? The impulse equation can solve this.

$$F \times 0.03 = 0.25 \times 20$$
$$F \times 0.03 = 5$$
$$F = 166.66 \text{ Newtons}$$

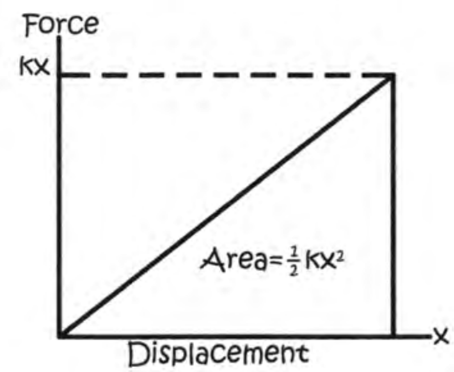
STANDARD 2G Students know how to solve problems involving elastic and inelastic collisions in one dimension by using the principles of conservation of momentum and energy. *Fernando*

Potential Energy of Springs

When you stretch or compress a spring, the force can start at zero, but will quickly rise as you stretch it. The restoring force is directly proportional to the displacement of the spring. Hook's law describes force vs. displacement for a spring as

$$F = kx$$

The graph to the right illustrates how the force varies when extending or compressing a spring. Since work done is force times distance, finding the energy stored in the spring is as simple as finding the area under the graph.



Peter

Mary

There are 3 different pogo-stickers. Peter is compressing the spring, Mary is at rest and Paul is in the air. Assuming all the children weigh the same and the springs are identical you can solve for the energy of the spring two ways. Using the information from Peter and Mary you can solve by using Hook's law and the formula

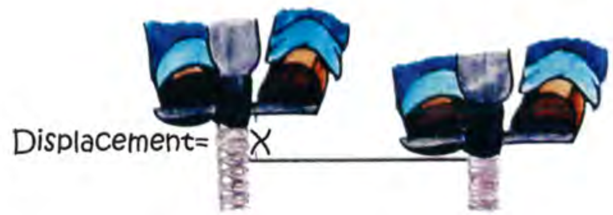
$$Work = \frac{1}{2}kx^2$$

The second way is using the information of Paul and the equation

$$Work = mgh$$

If the mass of the child is 20 kilograms and the total height form the pogo stick ot the ground is .25 meters. What is the total potential energy? (gravity is 9.8 m/s^2)

Paul

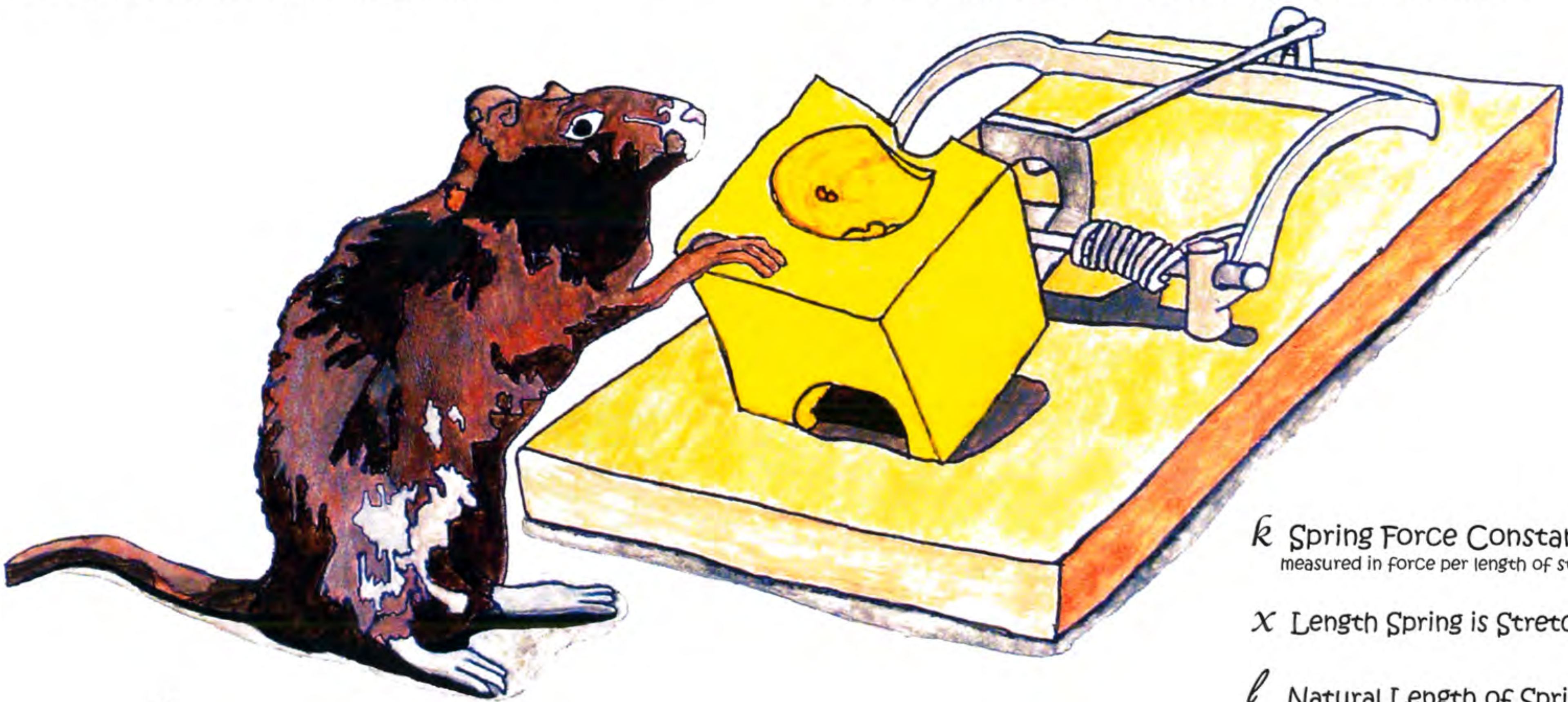


STANDARD 2H Students know how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs. *Ashley*

Conservation of Energy:

The total amount of energy remains constant throughout a system. Energy cannot be created or destroyed, but it can transform between various types of energies such as kinetic, potential, heat, and light. As the energy switches from one form to another we say that work is being done.

In this system potential energy is stored within the spring. We move the kill-bar into the set position by applying a force through a distance. When released, the spring does work on the bar by giving it kinetic energy. The kinetic energy of the bar, moving towards the mouse at high speed, is then available to do work on the mouse.

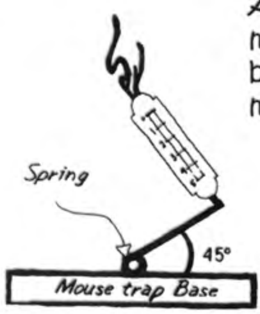


k Spring Force Constant
measured in force per length of stretching

x Length Spring is Stretched

ℓ Natural Length of Spring

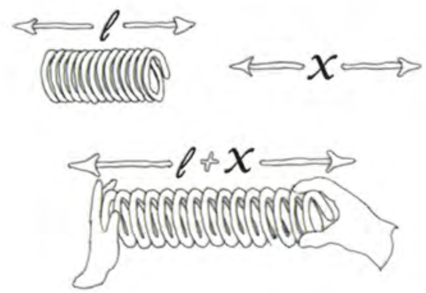
Angle (Degrees)	Force (Newtons)
0	2.5
45	4.5
90	6.5
135	8.5



A spring scale is used to measure the force exerted by the lever arm of the mousetrap.

$\frac{1}{2}mv^2$ Kinetic Energy

$\frac{1}{2}kx^2$ Spring Potential Energy



STANDARD 2H Students know how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs. *Kenny*

PHYSNEWTON final exam

Constants needed: $g = 9.81\ m/s^2$ $G = 6.67 \times 10^{-11}\ Nmkg^{-2}$

Conversions needed: 1 kg = 2.2 lbs 1 mile = 1609 meters

1. A pitcher throws a baseball, pushing on it with a force of 90 Newtons. If the pitchers hand is in contact with the ball over a distance of 1.5 meters, what is the kinetic energy of the ball as it leaves the pitcher's hand?

a. 60 J

b. 90 J

c. 101 J

d. 135 J

2. A 15 gram bullet is fired from a 1.8 kg gun. If the gun recoils at 2.5 m/s, at what velocity does the bullet leave the gun?

a. 0.25 m/s

b. 67.5 m/s

c. 300 m/s

d. 900 m/s

3. A 260 kg roller coaster car is 14 meters above ground level. What is the maximum kinetic energy it could gain by falling to a height of 5 meters on the first drop?

a. 22,900 J

b. 39,500 J

c. 66,800 J

d. 99,200 J

4. Which of the following best describes the trajectory of a football as it is passed between two players?

a. The ball travels in a perfectly straight line between the players.

b. The ball travels in a parabolic path as the vertical velocity is affected by gravity.

c. The ball travels in a circular orbit, being accelerated towards the earth's center at the same rate the ground curves away beneath it.

d. The ball travels upward at a constant velocity before falling back to earth at a constant speed.

5. Which of the following best describes the trajectory of a satellite in a low earth orbit?

a. The satellite travels in a perfectly straight line as it is not affected by gravity.

b. The satellite travels in a parabolic path as the vertical velocity is affected by gravity.

c. The satellite travels in a circular orbit, being accelerated towards the earth's center at the same rate the ground curves away beneath it.

d. The satellite moves along an octagonal path, occasionally changing direction by 45° to maximize the trajectory.

6. Three forces act on a 2.0 kg object as shown in the diagram to the right. What value could x be in order to keep the object from moving?

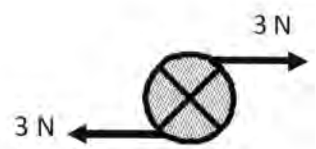
a. 0 Newtons

b. 6 Newtons

c. 12 Newtons

d. 18 Newtons

7. Two forces act on an object as shown to the right. What will the motion of the object be?



a. The object will remain motionless.

b. The object will move to the right.

c. The object will move to the left.

d. The object will begin to rotate.

8. A 60 kg man riding on a 20 kg bicycle is turning a corner at 10 m/s. If the radius of the curve is 5 meters, what force is acting on the bicycle in order to keep it turning?

a. 20 Newtons

b. 400 Newtons

c. 1,000 Newtons

d. 1,600 Newtons

9. The acceleration due to gravity at the Earth's surface, a distance of 6.38 x 106 m from the Earth's center, is 9.8 m/s^2. What would the acceleration be at twice this distance, 1.28 x 107 m from the Earth's center?

a. 9.8 m/s^2

b. 4.9 m/s^2

c. 2.5 m/s^2

d. 1.7 m/s^2

10. A moving car hits a stationary car at a stoplight. The road is very icy, and friction can be ignored. If the cars become tangled and move forward together, which of the following is conserved in this collision?

a. Momentum only.

b. Kinetic Energy only.

c. Momentum and Kinetic Energy.

d. Speed.

11. A man pushes on an un-moving wall with a force of 100 Newtons. What force does he feel the wall push back with?

a. 0 Newtons – walls cannot "push"

b. Less than 100 Newtons.

c. Exactly 100 Newtons.

d. More than 100 Newtons.

12. A yo-yo is whirled in a circle at a constant speed above a boy's head. Does it experience any acceleration?

a. No – since its speed is unchanging the acceleration must be zero.

b. Yes – there is an outward acceleration that gives rise to the centrifugal force.

c. Yes – there is an inward acceleration called centripetal acceleration.

d. No – acceleration only applies to objects rolling down hills.

13. A 90 kg sumo wrestler pushes on a little girl with a force of 120 Newtons. The girl has a mass of 20 kg and pushes back with a force of 30 Newtons. What is the acceleration of the pair?

a. 60 m/s^2 in the direction of the little girl.

b. 1.50 m/s^2 in the direction of the little girl.

c. 1.36 m/s^2 in the direction of the little girl.

d. 0.82 m/s^2 in the direction of the little girl.

14. Two perpendicular forces act on a 50 kg body which sits on a smooth frictionless surface: a 50 Newton Force acting due North, and a 100 Newton Force acting East. What is the resulting acceleration of the body?

a. 2.2 m/s^2.

b. 30 m/s^2.

c. 112 m/s^2.

d. 150 m/s^2.

15. When the speed of an object approaches the speed of light, which of the following happens?

a. Its mass decreases and it experiences time at a different rate to a stationary object.

b. Its mass decreases and it experiences time at the same rate to a stationary object.

c. Its mass increases and it experiences time at a different rate to a stationary object.

d. Its mass increases and it experiences time at the same rate to a stationary object.

16. A projectile is launched from ground level at a speed of 35 m/s and angle an angle of elevation of 45°. What is the distance from the launch point to the impact point?

a. 30 m

b. 90 m

c. 125 m

d. 250 m

17. A car weighing 1900 lbs is traveling at 50mph. What is its Kinetic Energy measured in Joules?

a. 950 J

b. 215 kJ

c. 325 MJ

d. 400 GJ

18. A stationary train is suddenly acted on by a 1000 Newton force pulling it forward. What is the train's momentum after 8 seconds?

a. 800 Ns

b. 1800 Ns

c. 6600 Ns

d. 8000 Ns

19. The gravitational attractive force between two objects increases when:

a. The distance between them increases.

b. The distance between them decreases.

c. The mass of one object decreases.

d. The mass of both objects decrease.

20. Impulse is most closely linked to a change in which quantity:

a. Momentum

b. Kinetic Energy

c. Potential Energy

d. Thermal Energy

Answer Key

1. d
2. c
3. a
4. b
5. c
6. b
7. d
8. d
9. c
10. a
11. c
12. c
13. d
14. c
15. c
16. c
17. b
18. d
19. b
20. a

HTH

ANOTHER GLOAG & ROBIN PHYSICS & ART SENIOR PROJECT